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Plant usage and subsistence modeling: An ethnoarchaeological approach to the Late Harappan of northwest India

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SEETHA NARAHARI REDDY

A thesis submitted in partial fulfillment of the

requirements for the degree of

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To

My Parents

who taught me the value of education

Jonathan Mark Kenoyer

who guided me in the pursuit of knowledge

and

My Husband, Brian

who helped me achieve my goal

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PLANT USAGE AND SUBSISTENCE MODELING:
AN ETHNOARCHAEOLOGICAL APPROACH TO THE LATE HARAPPAN OF NORTHWEST INDIA

Seetha Narahari Reddy
Under the supervision of Associate Professor Jonathan Mark Kenoyer
at the University of Wisconsin-Madison

ABSTRACT

This dissertation examines the importance of millets in pastoral and settled farming communities during the Late Harappan (2100 - 1300 B.C.) in Gujarat, India. The economic role and use of these summer crops are rigorously examined at the Late Harappan sites of Babar Kot and Oriyo Timbo in Gujarat, India, through a research design employing the complementary methods of ethnographic crop processing studies, archaeobotany, and carbon isotope analysis of domesticated animal bones. Particular attention is given to the potentially complex interplay and integration between pastoralism and agriculture during the Late Harappan times.

The ethnographic crop processing study entailed the development of ethnographic models of millet crop processing for archaeological application, and the isolation of variables that distinguish the products and byproducts of the processing stages. By applying these models to the archaeobotanical data, the presence or absence of crop cultivation and processing was determined and the character of Oriyo Timbo and Babar Kot economies defined. A distinct absence of millet cultivation by the site occupants characterized the pastoral Oriyo Timbo subsistence economy. In contrast, the positive identification of millet crop cultivation by Babar Kot occupants demonstrates

the presence of a settled farming community.

The insights gained from the research results at Oriyo Timbo and Babar Kot facilitate modeling of Late Harappan Gujarat settlement patterns by focussing on the degree of integration between agriculture and animal husbandry. Three potential settlement and subsistence system models are presented for future testing. It was previously argued that the breakdown in the Harappan integration sphere provided the impetus for expansion into new areas. This dissertation asserts that this trend entailed a sophisticated utilization of pastoralism and agriculture as integrated and complementing, and not alternative, economies during the Late Harappan phase in Gujarat.

The value of this dissertation lies in the application of new methods and the presentation of new data which have the potential to significantly redefine Late Harappan subsistence economies. Furthermore, the results generated from this study will have potential impact on several broader archaeological questions, including the antiquity of fodder cultivation and the crop processing techniques of early agriculturalists in general.

CHAPTER 1

INTRODUCTION

The principal aim of this dissertation is to investigate and elucidate the economic role, importance and cultivation of millet crops in Gujarat, northwest India, in the second millennium B.C. (during the Late Harappan). This is done through a research design employing the complementary methods of ethnographic crop processing studies, archaeobotany and carbon isotope analysis of domesticated animal bone remains. In this light, the project defines plant usage and models the subsistence at the Late Harappan sites of Babar Kot and Oriyo Timbo in Gujarat using an ethnoarchaeological approach.

The interplay between subsistence systems and settlements patterns, as noted in the Indus Valley, is a crucial variable in the interpretation of past economy and culture change. In the third millennium, the Mature Harappan in Gujarat was characterized by urban centralization, craft specialization, and a diversified subsistence economy. In contrast, the second millennium Gujarat Late Harappan is defined by the retention of specific Mature Harappan attributes but in a context of de-urbanization, expansion of settlements into new regions, possible changes in subsistence regimes, and the development of new regional traditions. Elucidating the nature and causes of these changes and continuity in settlement patterns and subsistence strategies in the context of Gujarat Harappan is the focus of this dissertation.

As compared to the Mature Harappan (2500 - 2000 B.C.), the Late Harappan phase (2100 - 1300 B.C.) in Gujarat, India, witnessed a significant increase in the number of settlements in arid locales along with a decrease in average site size (Bhan 1989). This proliferation of settlements has been ascribed to a shift in land use patterns as a result of an increased emphasis on pastoral animal husbandry (Bhan 1989; Rissman 1985) and the adoption and cultivation of summer crops - millets (Possehl 1986). This dissertation examines the economic importance and role of millets (as drought resistant

summer crops) in this Late Harappan context. Millet cultivation supplemented the existing non-farming subsistence practices such as pastoralism, and I further argue that in this context there was an increased integration between agriculture and pastoralism as complementary strategies rather than alternative strategies as suggested previously (Bhan 1989; Rissman 1985). In other words, the subsistence economies in play involved both agriculture and pastoralism integrated to different degrees within the same population, and they were not alternative adaptive strategies in the context of seasonality and availability of land or water.

Very little is known about the role of millets in the distinct economies of pastoralism and agriculture during the Late Harappan phase. The elucidation of the role of millet cultivation, if any, in the increased emphasis on animal husbandry (or more importantly in the integration of agriculture and pastoralism) is an important objective of this research. In particular, delineating the use of millet-byproducts or millet grain as fodder in `pastoral' settlements such as Oriyo Timbo and sedentary farming settlements such as Babar Kot, is a practical objective of this project.

Carbon isotope analysis of cattle bones is employed to identify the use of millets (which are C4 plants) as cattle fodder at these sites. Carbon isotope analysis, however, cannot be used to distinguish between the use of millet grains versus millet crop residues as animal fodder. This distinction is significant and has important implications. Ethnographic crop processing studies were carried out to distinguish the use of millet grains versus millet crop residues as animal fodder. These crop processing studies provided the basis on which predictive and interpretive models for archaeological interpretations were developed. The crop processing and usage models developed through these studies were then tested on the archaeobotanical assemblages from two Late Harappan sites, the sedentary settlement at Babar Kot and the pastoral camp of

Oriyo Timbo.

The organization of the dissertation is as follows. Chapter 2 provides the history and background to the research questions and problems. It presents the main issues in the study of the Harappan Phase in Gujarat, India, and places the main focus of this dissertation in its regional context. Chapter 3 is a comprehensive account of the theoretical and methodological approaches employed in this dissertation. Chapter 4 presents the ethnographic crop processing studies conducted in India, and includes the methodological account of the ethnoarchaeological fieldwork. Chapter 5 presents the data analysis of the ethnographic materials, and offers models for archaeological application. Chapter 6 focuses on the archaeobotanical research at the sites of Oriyo Timbo and Babar Kot, and includes a discussion of the methods used for collection, processing, and analyzing the archaeobotanical data presented in this dissertation. Chapter 7 deals with the archaeological application of the ethnographic crop processing models and interprets the archaeobotanical assemblages in this light. Plant usage models and subsistence modeling for the two sites studied in this dissertation are presented. Chapter 8 discusses the modeling of animal diet and fodder acquisition, and includes the methods and results of carbon isotope analysis. An animal feeding model for the Late Harappan phase in Gujarat is also presented. In chapter 9, the broader implications of the dissertation results for Late Harappan subsistence and settlement in Gujarat are addressed, and interpretations of Late Harappan systems are presented. Chapter 10 concludes the dissertation with a summary of the results and their implications to paleoethnobotanical interpretation, for the study of South Asian prehistoric agriculture and to archaeology in general.

CHAPTER 2

HISTORY AND BACKGROUND TO THE RESEARCH

Archaeological investigations of the earliest urban settlements in South Asia are focussed on the Indus Valley Tradition of Pakistan and northwest India. This dissertation addresses subsistence issues of this tradition, particularly during the Harappan phase. This chapter presents the geography, environmental setting and prehistoric cultural context for the research issues addressed in this dissertation, and then discusses the existing theories regarding the Harappan phase. A brief summary of the Indus tradition is followed by a detailed discussion of the Harappan phase in Gujarat. The concluding section of the chapter addresses the objectives and contributions of this dissertation in the context of the Harappan phase in Gujarat.

GEOGRAPHY AND ENVIRONMENTAL SETTING

The study area for this dissertation is northwest India, specifically in the modern state of Gujarat. It is the western-most state of India, and has an extensive Arabian Sea coastline, and has been described as an intrusion of the Indo-Gangetic conditions into the peninsula of India (Patel 1977). A distinctive feature of Gujarat is the seasonality inherent in the ecological aspects of the region. A brief discussion of the geography and environment of Gujarat is essential to fully understand prehistoric settlement patterns, subsistence strategies and culture change.

The modern state of Gujarat is comprised of two major geological zones, the Deccan Trap and alluvial riverine deposits. The Deccan Trap is a geological formation resulting from Mesozoic lava flows, one of the largest flows in the world (Patel 1977). Associated with this Deccan Trap are the black-cotton soils, which are formed insitu and are extremely important for subsistence agriculture. The particular character of these soils which makes them excellent dry cropping medium is their ability to swell

and absorb substantial amount of moisture. The Deccan trap formation dominates the lithology of peninsular Gujarat (Saurashtra), south Gujarat and Kutch (Figure 2-1). The alluvial deposits are mostly Pleistocene sediments deposited by the four main rivers of the region, the Sabarmati, Mahi, Tapi and Narmada rivers. The active plains, however, are recent (after 10,000 B.P.) Holocene sediments.

A subsistence perspective on the geography of Gujarat is offered by Patel (1977) who discusses the geography of the four main regions in Gujarat (South Gujarat, North Gujarat, Kutch and Saurashtra) in terms of agriculture. Gujarat is divided into these four regions based on geographical criteria and ethnic composition. South Gujarat is characterized by saline soils, and large tracts of pasture and grasslands in the west. High quality soils well-suited for agriculture characterize the central areas (Wadia 1966). North Gujarat is sandier and is also a much more arid plain. Relict Pleistocene sand dunes are present, and most of the rivers in this region are fed by the monsoon and ill-suited for irrigation (Leshnik 1968). The third region, Kutch, is very arid and is characterized by relict estuaries which are now salt flats created by the clay and sand deposits from minor rivers in the region (Gupta 1977).

Today, Saurashtra is the peninsula-like region of Gujarat with a central plateau and clayey black cotton soils known for their moisture retaining quality; however, during the Harappan times it is believed to have been insular. The archaeological sites of Babar Kot and Oriyo Timbo studied in this dissertation are located in Saurashtra and hence a more detailed discussion of its geography is necessary. This region is bounded by the Gulf of Kutch on the north, the Gulf of Khambhat on the south, the Arabian Sea on the west, and the marshes of the Nal Depression on the east (Figure 2-1). The Nal Depression is of particular interest for prehistoric, specifically Harappan, population movements. Spate and Learmouth (1967) have suggested that the Nal depression (which

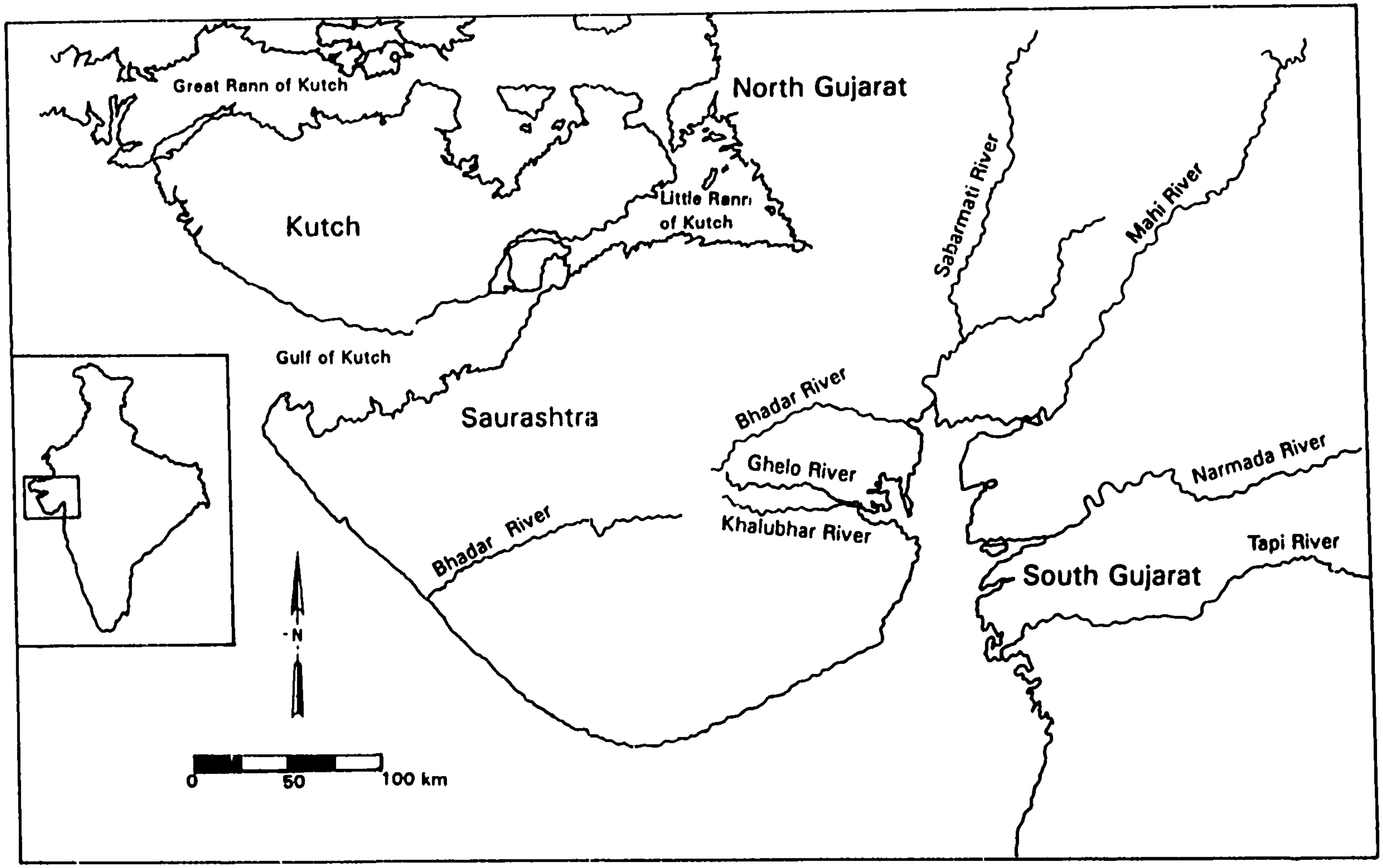


Figure 2-1. Map of Gujarat Showing the Geographical Regions

is described as a land bridge connecting Saurashtra to the mainland of Gujarat), may have been flooded yearly until 1813, effectively creating an island of Saurashtra. Rissman (1985:57) refers to the Imperial Gazeteer of the Government of India (1908: 170) in which 16th to 18th travelers accounts allude to an Indus River branch flowing by the town of Khambhat and thus separating Saurashtra from the mainland. Had this situation existed during the Harappan period (and something similar to this situation probably did exist), it would have had profound implications for the movement of populations from the Indus River valley to the Gujarat region, specifically in terms of restricting movements during certain seasons or facilitating the movements by river navigation.

Gujarat has a tropical climate; however, there is considerable variability within the region, with most of North Gujarat and the northern fringes of Saurashtra having an arid climate (Patel 1977). This region is comprised of large grasslands and isolated patches of tropical thorn forest. South Gujarat has a sub-humid climate with considerable vegetation cover and tropical dry forests. The remainder of the Gujarat area has a semi-arid climate with dry deciduous forested areas and generally poor vegetation cover (Patel 1977).

Seasonality is pronounced in Gujarat and is comprised of three distinct seasons, winter, summer and monsoon. The winter season spans from November to February, with December and January being the coldest months. The summer months of April and May are the hottest with maximum temperatures varying from 37.8°C in the south to 44.4°C in the north. The summer season is relieved by the onset of monsoonal rains in late June that continue into September, with July and August being the wettest months of the year.

The average precipitation per year is 60 cms; however, there is considerable variation from region to region. North Gujarat has an annual rainfall of 40 cms in the

west and 80 cms in the east. Rainfall in South Gujarat varies from 80 to 100 cms annually, while Kutch has less than 40 cms annually. There is a great deal of variation in the rainfall of Saurashtra, ranging between 40 to 75 cms annually.

There is a distinct homogeneity in the distribution of animals in Gujarat (Rissman 1985), although the densities may vary from one region to another. The Gujarat wild fauna includes Antilope cervicapra (blackbuck), Axis porcinus (hog deer), Boselaphus tragocamelus (nilgai), Canis aureus (jackal), Canis lupus pallipes (wolf), Cervus axis (spotted deer), Cervus duvanceli (swamp-deer), Cervus unicolor (sambar deer), Equus hemionus (half-ass), Felis tigris (tiger), Gazella dorcas (chinkara), Hyaena hyaena (common hyena), Panthera leo (asiatic lion), Sus scrofa (wild boar), Vulpes vulpes (fox), and a whole range of birds and small mammals (Rissman 1985). A variety of domesticated animals (cattle, sheep, goats, buffalo, dogs and chicken) is also present today.

In contrast to the faunal homogeneity, there are distinct differences in vegetation from one region of Gujarat to another dependent on annual precipitation, temperature and soils. Based on pollen data, it has been argued that the environment in Gujarat has changed little since the mid-Holocene. This position has been articulated in detail by Weber (1989) who refers to the works of Agrawal and Pande (1977), Mann (1955), Allchin and Goudie (1971), Allchin et al. (1978), Bhandari (1974, 1978), Bharadwai (1961), Gupta (1971a, 1971b), Gupta and Sharma (1982), Dodia (1988), Dodia et al. (1982) and Meher-Homji (1989).

Gujarat agriculture is primarily dry farming (85%) as a result of the black cotton soils and annual rainfall. In South Asia, sedentary peasant agriculture has two vitally important agricultural divisions: (i) wet and dry crops (ii) autumn (kharif) and spring (rabi) harvests. Dry farming is defined here as agriculture that is based on the

natural rainfall, and it is characterized by the absence of irrigation. In direct contrast, wet crops are grown with the use of irrigation, and thus wet farming is characterized by the presence of irrigation. Kharif or summer crops are monsoon crops, sown soon after the onset of the rains (June-July) and harvested in autumn. This includes rice, millets, sesamum, cotton and jute. In contrast, the rabi or winter crops are sown after the rains in June-July and harvested in the spring. This includes wheat, barley, gram, mustard and rape. A farmer can thus have two major crops on the same field each year.

Unlike wheat and barley, which are generally irrigated crops in Asia, the various millets (summer crops) including Sorghum (Sorghum bicolor), finger millet (Eleucine coracana), bulrush millet (Pennisetum typhoides), proso or common millet (Panicum milliaceum) and foxtail millet (Setaria italica), are cereals of rain fed agriculture throughout the semi-arid tropics. The summer crops tolerate a wide range of soil types and have a relative short warm-weather growing season. Today they are planted in South Asia principally on the Deccan plateau and in Gujarat. They are also cultivated in Baluchistan, Rajasthan, and along the western margins of the Indus Valley using moisture from summer floods (Patel 1977). Agricultural practices in Saurashtra are similar to the rest of Gujarat, with dry farming being the prominent subsistence economy, supplemented with varying degrees of pastoral nomadism by different sects of the population.

It is presently argued that the development of summer, rain fed, 'millet'-based agriculture in South Asia took place largely on the eastern and southern margins (southern Sindh and Gujarat) of the Indus Valley during the Harappan period (Possehl 1986). These areas have sufficient monsoon rainfall to support the dry farming of hardy, warmth-loving cereals. As Possehl (1986) has noted, the development and adoption of agricultural practices which directly used monsoon rainfall, opened up vast areas of Gujarat and the Deccan for dry-farming. Another benefit specific to millet

farming, is the production of animal fodder. Zebu cattle are particularly well-adapted to feeding in areas of marginal vegetation, but traditionally in South Asia they are fed millet stalks and occasionally the grain from second growth harvests (Randhawa 1962).

In a broad context, Meadow (1989) has argued for two distinct agricultural systems for the northwestern region of South Asia during the prehistoric and the protohistoric periods. The first involving the establishment by 4500 B.C. of a farming complex based principally on the rabi (winter sown, spring harvested) crops of wheat and barley. The second entailing the addition by 1900 B.C. of kharif (summer sown, fall harvested) crops such as Sorghum and other millets (Hutchinson 1977; Meadow 1989). However, Weber (1989, 1990) has demonstrated that millets were present in Gujarat, specifically at the site of Rojdi, from the mid-third millennium.

The next section places the main issue of this dissertation, the economic importance of kharif crops (summer sown, fall harvested) in Saurashtra during the third and second millennium B.C., into a cultural historical perspective. Geographical, ecological and climatic settings during the Harappan period are also discussed.

INDUS VALLEY TRADITION

Since its discovery in the 1920s, the Indus Valley Civilization has been the focus of much research and debate, particularly since it is South Asian's earliest urban society (Chakrabarti 1984; Jacobson 1987; Kenoyer 1991). The discussions of early urbanization have been based on extensive excavations at both large and small sites, and regional surveys (Bisht 1990; Dales and Kenoyer 1990; Jarrige 1986; Kenoyer 1989, 1991; Possehl 1980; Possehl and Raval 1989; Rissman and Chitalwala 1990). Recent investigations by Mughal in the Cholistan Desert (1982, 1988), in Punjab (Pakistan) by Dales and Kenoyer (1990, 1991), in Southern Indus by Dales (1979), Fairservis (1973),

in Baluchistan by Jarrige (1988), and in Saurashtra by Possehl (1980), Possehl and Raval (1989), Rissman and Chitalwala (1990) and Weber (1990), have all contributed to deepening our understanding of the Indus Valley cultural tradition.

In spite of these developments, South Asian archaeology (especially the Indus Valley civilization) has been subject to a great deal of criticism from scholars of other regions of the world, especially with reference to the interpretative theory. Much of the criticism points out the lack of extensive regional survey data from South Asia, and the tendency of many South Asian scholars to explain prehistoric diversity in South Asia in terms of similarities and differences with other regions of the world such as Mesopotamia, Egypt and Europe (Gupta 1979; Lamberg-Karlovsky 1982). Until recently progressive evolutionary theories have been common in the interpretations of South Asian prehistory, where specific culture change is viewed as one event in a ordered sequence of events. However, the limitations of such approaches are now being recognized and other explanatory models are being offered (e.g., Jarrige and Meadow 1980; Kenoyer 1991; Mughal 1982; Possehl 1980; Shaffer 1991; Weber 1989,).

Two key controversial issues in the archaeology of the Indus Valley civilization are chronology and terminology. Terms that are used liberally in the archaeological literature for the period between 4000 B.C. to 1500 B.C. in South Asia include Pre-Harappan, Early Harappan, Mature Harappan, Late Harappan and Post Harappan (Kenoyer 1991). Similarly, terms such as Early Indus and Mature Indus are also used without precise definitions. In addition, all the terms are used in reference to the urban character of the civilization at its zenith, and some scholars have recognized the limitations of such terminology (Kenoyer 1991; Shaffer 1991).

Shaffer (1991) proposed an explicit alternative, interpretating the Indus Valley archaeological record as a cultural tradition. Central to his comprehensive terminology is the heuristic concept of 'tradition' which he defines as "persistent configurations of

basic technologies and cultural systems within the context of temporal and geographical continuity" (Shaffer 1991: 442). In this conceptual framework, Shaffer (1991) identifies three major cultural traditions in northwest South Asia. Each tradition is divided into temporal eras (which are unrelated to geological eras) and phases. There are four distinct eras for the Indus Valley Tradition: Early Food Producing Era; Regionalization Era; Integration Era; Localization Era. Based on ceramic data, Shaffer identifies phases within each era. His framework is an effective approach to the massive archaeological record of the Indus Valley Civilization. Of concern to this dissertation are the Integration and Localization Eras in the Indus Tradition. The Harappan phase of the Integration Era begins between 2700 B.C. and 2500 B.C and occurs in the core regions of the Indus valley and Gujarat (Kenoyer 1991). The end of this Harappan phase is debated, and it is possible that it could continue up to 1900 B.C.

Kenoyer (1991) provides an excellent comprehensive discussion of the Integration and Localization Eras of the Indus Valley Tradition. For the purpose of this dissertation, which is only focussed on the Gujarat Harappan, and to reduce any confusion of terminology the terms Mature Harappan and Late Harappan are retained. The use of terms such as Mature Harappan and Late Harappan is considered the most appropriate for this dissertation since most scholars working in Gujarat have continued to use this terminology, and acceptance of Shaffer's (1991) framework is not universal. The term 'Mature Harappan' in Gujarat is equivalent to Shaffer's Harappan Phase (2500 - 2000 B.C.) in the Integration Era of the Indus Tradition, while the term 'Late Harappan' in Gujarat can be broadly equated to the Rangpur Phase (2100 - 1300 B.C.) of the Localization Era in the Indus Tradition (Shaffer 1991). It should be noted that there are other chronologies proposed for the Indus Tradition, and they vary slightly from Shaffer's (1991) chronology (c.f. Kenoyer 1991).

Protohistoric Environmental Setting

The protohistoric climate and environment are variables that played important roles in many theories regarding the Harappan phase of the Indus Valley Tradition (e.g. Raikes and Dyson 1961; Singh 1971). Both are viewed as delimiting factors in cultural adaptation and culture change in South Asia by many scholars working in this area. Therefore, the nature and interpretation of the climate and environment during the Harappan phase of the Indus Valley Tradition have drawn considerable interest and controversy in South Asian archaeology literature. The earliest scholars such as Marshall (1931), Dikshit (1938), Mackay (1943) and Piggott (1962) each argued that the protohistoric climate and environment were distinct from today. Since then, a series of studies have offered conflicting views on the climate. The most notable disagreement concerns the amount of rainfall, and interpretations have ranged from greater rainfall, to lesser rainfall or rainfall the same as today.

Singh (1971, 9177) is the most prominent proponent of the earlier theories which favored greater rainfall during the Mature Harappan of the Indus Valley Tradition. He used data from pollen sequences from lakes in Rajasthan, India, to argue that there was a moister climate in the past. This paleoenvironmental sequence indicates that there was increased rainfall (as compared to today) in northwest South Asia during the Harappan phase, which then decreased during the early parts of the second millennium B.C. Singh's sequence has been cited in climatic/environmental deterministic theories for the decline of the Indus Valley Tradition in northwest South Asia (Agarwal and Sood 1982; Singh 1977).

In contrast to the theories of greater protohistoric rainfall, there are a number of scholars who argue that the climate during the Harappan phase was similar to present times (Fairservis 1956; Hegde 1977; Raikes and Dyson 1961; Meadow 1989; Rissman and Chitalwala 1990; Possehl and Raval 1990). The data on climate and environment

that they use to support their interpretation also is derived from pollen studies. However, in general the climatic evidence for this area of the globe is very poor, primarily due to the lack of suitable deposits for long term pollen cores. Kenoyer (1991) notes that even if there were changes in rainfall, the area is so vast that it would not have affected all regions uniformly. Thus, scholarly debate on climate change or stability during the Harappan times remains unresolved since no definitive evidence has been obtained. If there were differences in rainfall, then the key questions would be the effect they had on the distributions of plant communities and the viability of different economic strategies. Shaffer and Liechtenstein (1989) contend that the northwest portion of South Asia did experience a series of climatic changes during the Holocene. However, the extent, timing, and duration of these fluctuations and cultural impact/responses are not researched and are poorly understood. For Gujarat, India, the available localized climatic data are generally interpreted as indicating no major differences between the third/second millennia B.C. and today (Meadow 1989; Rissman and Chitalwala 1990). In this dissertation, it is assumed that there have been no major fluctuations in Gujarat. Therefore, the general climatic and ecological discussions presented earlier for modern Gujarat are valid. The only difference would be the insular nature of Kutch, and possibly Saurashtra, which would have significant effects on the settlement of areas and movements of populations.

The Indus Valley Tradition: The Harappan Phase

The Indus Valley Tradition as defined by Shaffer (1991) and applied by Kenoyer (1991) includes cultural development in the Greater Indus Region from around 6500 B.C. until 1500 B.C. or later. This time span starts with food production, and includes regionalization, integration and finally localization. The focus of this dissertation, and

therefore the following discussion, is on the eras of integration and localization, particularly of the Harappan culture in Gujarat, India.

Kenoyer (1991) presents an excellent synthesis and review of the Indus Valley Tradition, with specific emphasis on the Integration Era in the Indus Valley. The urban state-level society of the Harappans was diverse and complex, with distinct regional expressions including the Gujarat Harappan. It is important to reiterate that these different regions (Gujarat, Punjab, Sindh and the main Indus River Valley) were not in isolation from each other (Kenoyer 1991; Meadow 1989; Possehl 1980). For example, Possehl (1979) proposed that pastoral nomads or other highly mobile (itinerant) occupational specialists moved between the different regions of the Indus civilization during the Mature Harappan Phase. Therefore, in spite of spatial distinction, there is considerable homogeneity in the Harappan culture communities from these various areas. There are also distinct stylistic and cultural signatures or markers which distinguish specific areas such as Gujarat, Sindh, or Punjab. The discussion in the following section is focussed on the Gujarat Harappan.

Gujarat Harappan

Definition and Broader Issues

Approximately 970 kilometers southeast of the site of Harappa, the geographical region referred to as the state of Gujarat in India is presently the southernmost extension of the Harappan cultural tradition. The Harappan of Gujarat is a distinct regional expression, and excavations at a number of sites have revealed a long history of Harappan presence in this region (Possehl and Raval 1989). Though on the periphery of the Harappan core area, it stands as a important region for the further understanding of the Harappan cultural sphere of interaction. Gujarat appears to have been settled by Harappans from the greater Indus region around 2400-2300 B.C., based on radiocarbon

dates from the sites of Lothal and Surkotada (Possehl and Raval 1991) (Figure 2-2).

The regional Harappan expression in Gujarat has been recognized and redefined by Possehl and Raval (1989). They have noted that Rojdi and many other sites in Gujarat represent a newly discovered regional expression of the Mature Harappan phase, which clearly is a part of the larger Harappan cultural entity (Possehl and Raval 1989). Some of the excavated Mature Harappan sites in Gujarat such as Lothal, Rangpur, Surkotada and Desalpur, have a typical Mature Harappan material culture inventory that includes inscribed seals, distinctive ceramics, metal works, beads, and substantial public architecture. This aspect of the Indus civilization in Gujarat is referred to as the 'Sindhi' Harappan by Possehl and Raval (1989), since it closely resembles materials from the Indus core sites which are found in Sindh, Baluchistan, Punjab, North West Frontier Province and Haryana. In this dissertation, the term 'core area' is used in place of Possehl and Raval's (1989) term 'Sindhi'. Radiocarbon dates place this phase between 2500 B.C. and 2300 B.C.

There are, however, a whole set of Mature Harappan sites in Gujarat (including the site of Rojdi), particularly in Saurashtra, which are distinctive from the core area Harappan sites. Their material culture inventory is relatively simple compared to other Mature Harappan sites. For example, there is the noted absence of stamp seals and ornaments are rare, and architecture is not elaborate. Possehl and Raval (1989) argue that these sites represent a distinctive and new regional expression of the Mature Harappan Phase which they termed 'Sorath' Harappan. They argue that it is stylistically divergent from the core area Mature Harappan (as known from the Mature Harappan sites in Sindh and Kutch) but still part of the Harappan integration sphere. In general, the 'Sorath' Harappan sites are small (about 5.3 hectares) with little range in settlement size, and they have relatively simple material culture (Possehl and

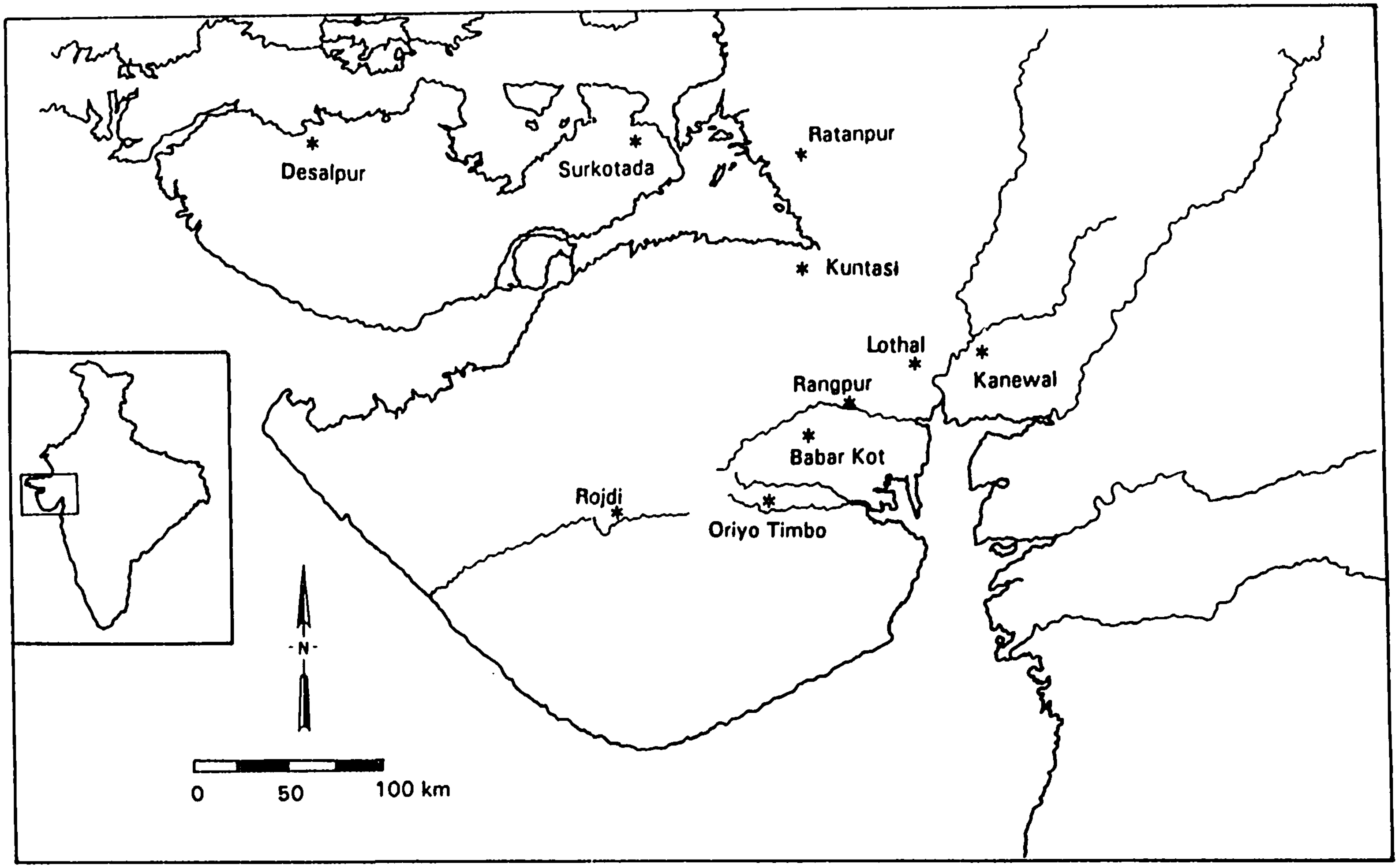


Figure 2-2. Map of Gujarat Showing the Major Archaeological Sites Mentioned in the Text

Raval 1989). Both sites studied in this dissertation, Babar Kot and Oriyo Timbo, are 'Sorath' Harappan. Babar Kot is described as a Late 'Sorath' Harappan site (Possehl and Raval 1991), while Oriyo Timbo was occupied during the final phase of Late 'Sorath' Harappan (Possehl 1990; Possehl and Raval 1989). However, to reduce and avoid inevitable confusion in terminology, the two sites studied (Oriyo Timbo and Babar Kot) in this dissertation are referred to as Late Harappan sites.

As perhaps evident from discussion in this chapter the confusing and unresolved chronology is a major difficulty inhibiting advances in the study of the Gujarat Harappan. One reason for this lack of resolution is that until very recently ceramic chronology was the fundamental and often the only form of dating used for the Gujarat Harappan. Therefore, the Gujarat Harappan literature is filled with discussions of ceramic chronological sequences, and very often the Mature Harappan site of Rangpur is the reference site. Other sites are then equated and compared to the Rangpur ceramic sequence, and the reader has to contend with chronological terms such as Lothal B, Rangpur IIB/C, Rojdi B, and so on. Radiocarbon dates obtained in the last decade or so have helped resolve some of the confusion. The Rangpur sequence is generally equated to the major Harappan phases as follows: Rangpur II A - Mature Harappan; Rangpur II B-C - Late Harappan; and Rangpur III - Post Harappan. However, directly equating the Rojdi ceramic sequence (Rojdi being the key site for 'Sorath' Harappan) to the Rangpur sequence is not possible. However, an approximate temporal equation yields three phases (earliest to latest): Rojdi A (similar to Rangpur IIA), Rojdi B (late Mature Harappan phase) and Rojdi C (Late Harappan phase). For the purpose of this dissertation, a chronological sequence compiled from Bhan (1989), and Possehl and Raval (1989) is adopted (Table 2-1).

Table 2-1. Gujarat Chronological Sequence

RANGPUR	ROJDI	PHASE	DATES
II A	A	MH	2100 - 2000 B.C
II B-C	B, C	Initial LH	?2000 - ?1700 B.C
III		Final LH	?1700 -?1400 B.C

MH=Mature Harappan
LH=Late Harappan

The two sites of Babar Kot and Oriyo Timbo studied in this dissertation are temporally equivalent to Rojdi C and Rangpur III sequences respectively. Therefore, both Babar Kot and Oriyo Timbo are Late Harappan sites, of the local 'Sorath' Harappan expression in Gujarat.

The results from the excavations of Rojdi and the identification of the 'Sorath' Harappan by Possehl and Raval (1989) suggest that Harappan populations were extensive in Gujarat at an earlier date than had previously been expected. The original interpretation was that during the Mature Harappan phase small numbers of Harappans migrated to Saurashtra from Sindh (Possehl 1976). However, a more complex picture of the past is now emerging with the identification of local ('Sorath') and non-local (core area Harappan) cultures. The presence of the 'Sorath' Harappan, with Rojdi A and B being distinctive from Mature Harappan sites in Sindh, implies an indigenous line of development within Gujarat beginning by 3000 B.C. (Possehl and Raval 1989). The core area Harappan may have come into Gujarat, particularly Saurashtra, as a distinctive and separate migration about 2400 B.C. In spite of these recent developments, the Harappan phase in Gujarat is yet to be fully understood.

One important issue in South Asian archaeology that has remained unanswered

deals with the causes for a distinct 'deurbanization' of the greater Indus Valley beginning about 2000 B.C. (Meadow 1989). Along with this phenomenon was the emergence of distinctly local manifestations of material culture (such as 'Sorath' Harappan) that are particularly striking when compared to an extent of integration evident during the Mature Harappan phase (Meadow 1989). There are also significant shifts in settlement patterns including the eventual abandonment of certain very large sites (including Mohenjo-daro and Harappa), and an increase in smaller settlements throughout the region and particularly in the east Punjab (Joshi et al. 1984; Shaffer 1981) and Gujarat (Possehl 1979). Some abandonments and realignments have been attributed to changes in hydrological regimes in Punjab (Mughal 1982; Wilhelmy 1969) and in Sindh (Flam 1981). Meadow (1989: 68-70) argues that there is increasing evidence in the middle of the second millennium B.C that a new complex of cereal crops (millets) and domestic animals were utilized in the eastern and southern margins of the Mature Harappan cultural sphere. This assertion has been refuted by Weber (1989), who points out that there is no second millennium 'revolution' in the subsistence base in Gujarat (which is the southern most extention of the Harappan cultural sphere) since millets are present from the mid-third millennium B.C in this region. If indeed a major change took place, Weber (1989) maintains that it took place at an earlier time.

In Gujarat, the Mature Harappan is characterized by urban centralization, craft specialization and a diversified subsistence economy. The Late Harappan of Gujarat in contrast is defined by the retention of specific Mature Harappan attributes but in a context of de-urbanization, expansion of settlements into new regions, changes in subsistence regimes, and the development of new regional traditions in ceramics for example. Changes and continuity in settlement patterns and subsistence strategies in the

context of Mature and Late Harappan of Gujarat are addressed in further detail below.

Settlement Patterns

The extensive survey data in Gujarat indicates that during the second millennium there were several significant changes in the nature and distribution of settlements of the Harappan integration sphere (Bhan 1989; Possehl 1980). This period witnessed, among other things, an increase in the number of small sites coupled with the possible or partial abandonment of the larger urban sites, a decrease in elite goods (such as seals, beads and metal works) and the decreased use of Harappan weight and writing systems. These changes have been interpreted as being due to the 'collapse' or decline of the Harappan state, and a decreasing complexity of political and social systems as compared to the earlier Mature Harappan.

The task of elucidating the changes and continuity in Gujarat from Mature Harappan to Late Harappan is challenging, and scholars have offered different perspectives (e.g., Bhan 1989; Herman 1991). Herman (1991) argues that there is a distinction between Harappan settlements of Kutch and Saurashtra beginning during the Early Harappan. The Harappan economy in Kutch included extensive production and then trade of valuables throughout the Harappan interaction sphere. The Harappan emphasis in Saurashtra, in contrast, was on herding and farming, and the interaction sphere did not extend much outside of Gujarat. Thus, regionality and locality were more important for the Harappans in Saurashtra, as compared to the Harappans in Kutch who were involved in trade outside the Gujarat area from the early Harappan times. According to Herman (1991), the subsistence strategies were similar, with both areas being reliant on cattle herding and millet subsistence. With the intensification of the urban process during the Mature Harappan period, factory settlements were set up in Saurashtra by the Harappans of Kutch. In the Late Harappan (starting around 2000

B.C.) localization became heightened and the local interaction between Kutch and Saurashtra intensified owing to the breakdown of interaction spheres with the core areas to the west and outside the Gujarat region. Herman (1991) does not attempt to explain the increase in the number of settlements during the Late Harappan, and instead emphasizes the Kutch/Saurasthra dichotomy. His study of the Gujarat Harappan also does not take account of the relationship between settlement patterns and subsistence strategies which is particularly important in a semi-arid/arid environment.

In contrast, Bhan's (1989) study of Late Harappan settlements in Gujarat takes into consideration the implications of settlement patterns for subsistence strategies. He examines variation in the settlement pattern between Kutch and Gujarat from Mature to Late Harappan in relationship to subsistence strategies. Summarizing his study, the Mature Harappan settlements in Gujarat are significantly less infrequent compared to Late Harappan settlements, and most are situated in the Kutch region (Table 2-2). These differences are interpreted using an expansionist theory which argues that the Kutch Mature Harappan sites were administrative settlements, while those in Saurashtra (such as Nageswar and Lothal), were manufacturing satellite settlements. Thus, Bhan (1989) argues that the Mature Harappan settlement pattern developed mainly to facilitate trade, access to raw materials, and administrative activities, and not solely due to subsistence related purposes. He also suggests that the establishment of satellite settlements in Saurashtra increased toward the end of Mature Harappan with a deterioration of the integration with the core area. The Late Harappan is divided into an initial and a final phase, and Table 2-2 shows the distribution of sites with the use of the Rangpur ceramic chronology.

The interplay between subsistence systems and settlement patterns, is a crucial variable in the interpretation of past economy and culture change. Thus, in comparison

Table 2-2. Harappan Settlements in Gujarat

Rangpur	Phase	Total Sites	Kutch	Saurashtra
II A	MH	20	14	6
II B-C	Initial LH	152	?1	?151
III	Final LH	79	30	49

MH= Mature Harappan
LH= Late Harappan

(From Bhan 1989)

to the Mature Harappan period (2500 - 2000 B.C.), the Late Harappan period (2100 - 1300 B.C.) in Gujarat witnessed a significant increase in the number of settlements in the arid regions (Bhan 1989). This increase was accompanied by a decrease in average site size, and these trends have been ascribed to a shift in land use patterns resulting from an increased emphasis on pastoral animal husbandry (Bhan 1989; Rissman 1985), and the adoption of summer crops, i.e., millets (Possehl 1986).

The fluctuation in site count during the Late Harappan (Table 2-2) is attributed to changing mobility mainly due to pastoralism. As suggested by Rissman (1985), there is a shift from cultivation to pastoral production in the final phase of Late Harappan. Both Bhan (1989) and Rissman (1985) argue that the need for the maintenance of large herds exerted pressure on mobility, and thus the location of settlements in traditional pasture lands was an inevitable outcome in the context of such an economy. This trend is supported by the concentration of the North Gujarat/Kutch Late Harappan settlement in the western part where the agricultural potential is low but excellent grasslands are optimal for a pastoral economy.

Bhan (1989) suggests that two different categories of settlements developed

during the Late Harappan in Gujarat; abundant small villages or dry season pastoral camps with simple round huts, and fewer but larger sedentary farming settlements with permanent mud brick or stone rubble architecture. Although there are no artifactual ties between these types of settlements, the two tier subsistence system (first suggested by Rissman 1985) has great interpretive value for the studies of Late Harappan settlement and subsistence systems in Gujarat.

In this context of interplay between subsistence systems and settlements patterns, the economic importance and role of millets, drought resistant summer crops, at pastoral versus agricultural settlements during the Late Harappan needs to be elucidated. If indeed there was a deliberate shift from cultivation to pastoralism during the Late Harappan as argued by Rissman (1985), it is imperative to address this issue at both types of settlements: pastoral and farming. It is also important to model for possible interrelationships in subsistence between the two different categories of settlements proposed by Bhan (1989). Thus, this dissertation examines the role of millet crops at the two types of Late Harappan sites (pastoral and farming). The hypothesis is that since millet cultivation in Gujarat was not a 'revolution' as previously suggested by Meadow (1989), it supplemented existing non-farming subsistence practices such as pastoralism. The elucidation of the role of millets, if any, in the increased emphasis on animal husbandry (or integration of agriculture and herding) is a goal of this research. In particular, the use of millet byproducts or millet grain as fodder in 'pastoral' settlements such as Oriyo Timbo and sedentary farming settlements such as Babar Kot, is a key focus of this project. Since the elucidation of Late Harappan subsistence practices is an integral component of this dissertation, further discussion and background information on the subject is presented in the following section.

Subsistence Strategies

A subsistence pattern based principally on the winter crops of wheat and barley, and on domestic cattle was established in the Greater Indus Valley by the sixth millennium B.C., and it formed the agricultural foundation for the Indus Civilization (Meadow 1989). The subsequent diversity of the Harappan subsistence systems is a much debated topic. Subsistence studies of the second millennium have focused on the apparent introduction of millets and associated secondary 'revolution' in the subsistence systems. Meadow (1989), the main proponent of this second 'revolution', based his argument on faunal data since horse and donkey first appear at Harappan sites at the start of the second millennium. He suggested that millets were included in this corpus of new domesticates. Since then, however, Sharma (1992) has confirmed the presence of domesticated horse during the Mature Harappan, and more specifically at the site of Surkotada in Gujarat.

Possehl (1986) argued that the proliferation of the Late Harappan settlements in Gujarat was due to the introduction and adoption of millets into the subsistence base. However, Weber (1989, 1990), through his archaeobotanical research at the Late Harappan site of Rojdi in Gujarat, has demonstrated that millets were present in the area from the mid-third millennium. Nonetheless, it is plausible that the introduction and cultivation of millets in the region made the proliferation of settlements possible since they are more arid adapted crops and grow in wider range of soils as compared to the winter crops.

There is meager evidence of winter crop cultivation in Gujarat in the form of a few barley grains from the lowest levels of Rojdi (Weber 1989). Weber (1989) argues that barley could have been traded instead of having been grown locally. Additionally, the evidence of agriculture from sites prior to about 2500 B.C. is non-existent, mainly because the importance of studying subsistence economy and retrieving

archaeobotanical materials has only recently been recognized. As the range of questions being asked about the relationships between people and plants widens, archaeologists are rapidly moving beyond descriptive lists of species (Hastorf and Popper 1988). The focus has shifted to total assemblages and additional lines of evidence such as ethnographic studies, bone chemistry, soil geology and phytolith studies are being investigated and integrated into interpretive models (Pearsall 1982; Reddy 1991b). With the exception of Rojdi, and the two sites studied for this dissertation (Oriyo Timbo and Babar Kot) there are very few sites from which any archaeological plant remains have been recovered and studied. Plant materials were recovered from the Gujarat Harappan sites of Surkotada, Lothal and Rangpur (Ghosh and Lal 1962/3; Vishnu-Mittre and Savitri 1982), but the sampling strategy and methods were not intensive enough to answer the major question regarding the Mature and Late Harappan in Gujarat.

The earliest archaeobotanical samples available from Mature Harappan sites in Gujarat include 'millets'. Since millets such as Panicum miliare, Setaria italica, Eleucine coracana, Sorghum bicolor and Pennisetum typhoides are considered to be non-native and have been brought into Gujarat from elsewhere, the timing and dynamics of this process is much debated (Weber 1989, 1990). In general, understanding the adoption of new domesticates and agricultural practices has been overshadowed by research interest in indigenous origins of agriculture. The reasons and rewards for adding a new crop plant into an existing subsistence system are rarely discussed as a specific issue, and the motivation for people to begin to grow domesticates introduced from elsewhere remains ellusive. To what extent the practice of agriculture itself may have been an indigenous development in Gujarat rather than introduced from elsewhere is impossible to say at this point in time. Not only is very little known about early agriculture in the Gujarat region, but there are no plant remains

reported from any pre-agricultural (Mesolithic) sites in the area. A question often raised but to date not answered satisfactorily, concerns the appearance of millets in South Asia. Where did these crop plants that have been grouped under the term 'millets' come from originally?

There are various theories on the center of origin for the different millets. The millet plants relevant to this dissertation are Setaria italica, Panicum miliare and Eleucine coracana. An East Asian center of origin is suggested for Setaria italica by Werth (1937) and Rao et al. (1987). A South Asian and an East Asian center have both been suggested for Panicum miliare (Chalam & Venkateswarlu 1965; Ho 1975; Werth 1937; Vavilov 1959). And lastly, an African and a South Asian center of origin has been suggested for Eleucine coracana (Dixit et al. 1987; Mehra 1963; Savitri & Vishnu-Mittre 1979; Werth 1937). While the debate continues on the natural habitat of Panicum miliare and Eleucine coracana, it seems reasonable to assert that Setaria italica was introduced into South Asia from East Asia.

The patterns and processes leading to the introduction and the adoption of these cultivars is of great significance, although addressed infrequently. It is conceivable that Setaria italica was brought into South Asia by the seasonally migrating pastoral groups traveling the area between east-central Asia and Gujarat. The pivotal question in such a scenario is why would it have been beneficial for the South Asian populations to adopt these new cultivars? And additionally, why was the cultivar not adopted in areas in between the two regions? I suggest that there may be other reasons for adoption apart from human consumption. Millets have historically been very attractive fodders. It is plausible that use as animal fodder was the incentive for the initial South Asian interest in a plant such as Setaria italica. By investigating whether millets were used as fodder in the Mature and Late Harappan, new models of explanation can address the process of millet adoption in Northwest India (Reddy 1991a).

Prior to this dissertation project, most of the information on Gujarat Harappan agriculture comes from the sites of Rangpur (Ghosh and Lal 1962/3), Surkotada (Vishnu-Mittre and Savitri 1982), Rojdi (Weber 1989) and Oriyo Timbo (Wagner 1989). The archaeobotanical data from all these sites are most indicative of summer crop cultivation, mainly of millets. The archaeobotanical remains from Rangpur and Surkotada are only from one or two samples, and therefore the results are limited compared to the rigorous methods of recovery and study at Rojdi (Weber 1989) and Oriyo Timbo (Wagner 1989). The millet crops recovered from the Gujarat Harappan sites include Panicum miliare, Eleucine coracana, Setaria italica, Sorghum sps and Echinochloa sps. Even though a wide range of millet crops was recovered from Harappan sites in Gujarat, all the millets were not in use throughout the Harappan phase (Mature through Late). For example, based on the study of archaeobotanical materials recovered from Rojdi, Weber (1989) argues that Setaria italica did not become a prominent cultigen until after 2000 B.C. Although his argument is based on a single site, such changing emphases on different crops over time is not inconceivable. This could be a result of changing demands by the community and its subsistence system. For example, certain crops might be preferred over others at one point for their higher yields of vegetative parts which are vital for fodder, fuel or building materials.

Other evidence of agriculture in the Gujarat Harappan comes from impressions on pottery, the presence of a granary at Lothal and the nature of settlements. The size of the larger Harappan towns (and indirectly the population) in Gujarat made plough agriculture a necessity. However, no ploughs have been found from Harappan sites in Gujarat, although a possible ploughed field of the pre-Harappan levels of Kalibangan is often cited as evidence. Other evidence of agricultural practices includes a seal found at Lothal which depicts an object interpreted by Rao (1973) as a seed drill; however, it is

an unusual shape for a seed drill.

The existing data on Gujarat Harappan agriculture (both Mature and Late) come from select few sites and thus place constraints on interpretive modeling. Additionally, since there is no information on agricultural practices prior to 2500 B.C., the issue of elucidating the subsistence strategies of the Late Harappan is further complicated. The general consensus regarding Gujarat Harappan subsistence is that animal herding was an important activity during the Mature Harappan and that this strategy increased in the Late Harappan. In addition, summer crop cultivation was practiced and was supplemented by wild plant and animal exploitation, and winter cultivation has also been suggested despite minimal evidence.

RESEARCH OBJECTIVES

The Late Harappan phenomenon in Gujarat, although subject to considerable research, is yet to be fully defined. Investigations have focussed on much needed settlement pattern surveys and site excavations, but with the exception of Weber (1989) and Reddy (1990, 1991) there has been a general neglect of subsistence studies in Gujarat. The objective of this dissertation is to define the economic role and importance of summer crops, specifically drought resistant millets, during the Late Harappan in Gujarat.

As discussed earlier, the Late Harappan phase (2100 - 1300 B.C.) in northwest India, specifically Gujarat, witnessed a significant increase in the number of settlements in arid locales along with a decrease in average site size (Bhan 1989). This proliferation of settlements has been ascribed to a shift in land use patterns as a result of an increased emphasis on pastoral animal husbandry (Bhan 1989; Rissman 1985) and the adoption and cultivation of summer crops - millets (Possehl 1986). With cultivation of millets as the basis of the subsistence economy, expansion into the arid portions of Gujarat could

have been facilitated with minimal risk. The objective of this dissertation is to elucidate the importance of millets (and their cultivation if any) to Late Harappan pastoral communities and to settled farming communities. In this light the dissertation examines and defines the economic role and use of these summer crops at the two Late Harappan sites of Babar Kot and Oriyo Timbo.

Another objective of this dissertation is to determine if there was increased cultivation or use of millet plants for animal fodder during this phase. This would help elucidate the interplay and the integration between pastoralism and agriculture during the Late Harappan times. Based on ethnographic and ethnobotanical observations of present day Gujarat this relationship could have been quite complex. The most detailed and rigorous examination of the range of adaptations and interactions between pastoralism and agriculture has been conducted by Khazanov (1984). Khazanov's (1984) definitions of the various pastoral nomadic adaptations are based on the degree of dependence on agriculture by pastoralists, and include five broad categories: pastoral nomadism; semi-nomadic pastoralism; semi-sedentary pastoralism; herdsman husbandry; sedentary animal husbandry. Pastoral nomadic adaptation is distinguished by the complete absence of agriculture. Semi-nomadic pastoralism is characterized by pastoralism being the dominant economic activity, with agriculture often playing a secondary, supplementary role. The two economic activities could be practiced (often on a seasonal basis) by different segments of the same group or not. Semi-sedentary pastoralism is distinguished from these two pastoral adaptations, since agriculture is the dominant economic activity, but seasonal pastoral activities are also important economically. Again, certain segments of the group may participate in these pastoral activities on a seasonal basis. Herdsman husbandry, or distant-pastures husbandry, entails pastoral activities pursued by specialists with the majority of the group being

sedentary agriculturalists. The final form of pastoralism, sedentary animal husbandry, only functions to supplement agriculture which is the predominant economic practice. Khazanov (1984) emphasizes that there are many variants in each of these basic forms of pastoralism. The differences between each form, however, have profound implications that need to be elucidated to fully understand the Late Harappan cultural, socio-economic and political changes. Therefore, this dissertation uses Khazanov's (1984) classification of pastoral adaptations to study the Late Harappan subsistence and settlement systems.

One proposed working hypothesis is that the millets may have been cultivated on a small level by the Late Harappan pastoral groups as animal fodder (Reddy 1990). If this is supported then the resulting system is more akin to semi-sedentary pastoralism, semi-nomadic pastoralism or herdsman husbandry, and not pastoral nomadism as proposed by Rissman (1985) and Bhan (1989), since fodder cultivation is the hallmark of a highly integrated system of agriculture and herding (Khazanov 1984).

Despite the research done to date, cultivation of the millets as an economic activity has not been identified at any Harappan sites in Gujarat. The simple recovery/retrieval of archaeobotanical millet seeds from the sites is not adequate enough to argue for cultivation, since the grains could have been obtained from outside the site by the occupants. Identification of the cultivation practice is important to minimize concern that millet crops grain were being obtained by the Gujarat Harappans of a particular site through trade from elsewhere (from settlements within and/or outside the region). Such research can be accomplished through the application of ethnographic models as done by Hillman (1984) and Jones (1987) for wheat and barley in the Near East and Greece, and suggested by Reddy (1990) for millet cultivation in the Late Harappan in Gujarat.

This dissertation includes the study and ethnographic modeling of millet crop

processing for archaeological application (chapters 4 and 5). Therefore, in this dimension, ethnographic observations particularly designed for archaeobotanical interpretations, as done in this dissertation, are rare with the exception of Hillman (1981, 1984) and Jones (1987), and have never been done in a South Asian context, or for millet crops. The results will therefore contribute to the methodology of agricultural ethnoarchaeology, and research design in the fields of archaeobotany and ethnobotany. Given, the current rudimentary understanding of South Asian subsistence systems, the results of this research have the potential to provide a firm foundation for future studies. This dissertation by no means answers all the questions regarding the Late Harappan phenomenon in Gujarat, India. It is meant to provide new approaches, and offer new innovative investigatory methods to facilitate the first steps towards gaining a better understanding of the subsistence and agricultural systems of Late Harappan in Gujarat. For example, if the results of this dissertation aid in the definitive paleoethnobotanical identification of millet crop cultivation as an economic activity at different types of sites (pastoral and farming), then it will be possible to comment on the degrees of integration between agricultural and pastoral economies at these specific Late Harappan sites. This would help elucidate and comment on the probability of changing economies as proposed by Rissman (1985) (decreased farming and increased pastoralism) during the Late Harappan phase in Gujarat.

In addition, the results from this project would also be of significance to modern problems in India, specifically those related to the success and failure of particular subsistence strategies over time. The results could be a reference for the much needed historical depth to India's increasing problem of successful subsistence strategies in semi-arid environments.

The next chapter presents the theoretical and methodological background

relevant to subsistence studies of prehistoric agricultural societies, globally and specifically to South Asia. It also discusses the theoretical approach chosen in this dissertation to study the Late Harappan subsistence systems.

CHAPTER 3

THE THEORETICAL AND METHODOLOGICAL APPROACH

INTRODUCTION

Early cultural ecological studies (Steward 1938) established the importance of the relationship between human populations and the environment. Since then there has been tremendous progress in the study of prehistoric subsistence strategies, particularly in the realization of the important interaction between humans and plants (Harris 1989; Hastorf and Popper 1988; Hillman 1984; Jones 1983). The study of human subsistence systems involves investigation of the interaction between humans, technology, and floral and faunal resources. In particular, the relationship between humans and plants within a past culture provides valuable information about the culture itself since plants satisfy the basic needs of food, fuel, shelter and tools (Popper and Hastorf 1988). Additionally, plant resources have significant roles in religious practices and other social activities. In this light, there is a growing global interest in the study of agricultural practices from charred remains of crop plants, and the range of questions being asked about the relationships between people and plants are widening. Unfortunately, a sound methodology linking archaeologically recovered plant remains to past human agricultural practices has often been lacking; it is often difficult to properly interpret plant remains recovered from the archaeological record. This problem is being recognized (Hillman 1984; Hastorf and Popper 1988; Jones 1987), and rigorous methods and interpretive models are now being developed. This chapter presents the theoretical and methodological issues relevant to subsistence studies of prehistoric agricultural societies, globally and specifically to South Asia, followed by a discussion of the approach chosen in this dissertation to study Late Harappan subsistence systems (ethnographic crop processing studies and paleoethnobotany). Then

the issues and problems related to ethnographic crop processing studies and paleoethnobotany are presented in the subsequent sections. The concluding section of the chapter discusses the need for such an integrated approach to address the questions posed in this dissertation.

THE STUDY OF SUBSISTENCE SYSTEMS

The study of economic and subsistence systems remains a major focus of archaeological research mainly because food acquisition and production systems have long been considered the most recoverable of all cultural phenomena (Hastorf and Popper 1988). Additionally, subsistence has historically been viewed as a central, if not driving, variable of culture change (for a notable reference see Morgan 1963). This correlation between subsistence and culture change has been implicit within much of archaeological theoretical discussion. For example, it is an operating assumption within the research domain of economic prehistory advanced by Clark (1936, 1954) and elaborated on by Higgs (1972, 1975). This theoretical orientation considers economy and ecology as the keys to understanding prehistory, culture change and subsistence strategies.

Materialistic approaches predominate the theoretical perspectives for subsistence studies. For most anthropologists, a cultural materialist approach signifies a philosophical view that accords greater importance to a society's behavior than its thoughts, reflections, or justification for its behavior (Kohl 1981). The relationship between material remains and human behavior is the basis for most archaeological studies. As such, materialist approaches are well-suited for paleoethnobotanical investigations that examine the relationship between archaeobotanical remains and human behavior. Materialist interpretations range from crude determinism, in which

societies only respond to environmental changes or demographic pressures, to more ecological explanations in which cultures adapt to external stimuli (Kohl 1981). Although there is a great plurality in materialist perspectives, cultural, ecological and economic materialist approaches predominate and are specifically discussed in this chapter.

Cultural materialist approach is often considered the dominant theoretical orientation in archaeology (Kohl 1981, Harris 1979), and is pervasive in subsistence studies. In this perspective, subsistence strategies are the interface between culture and environment. Marvin Harris is the undisputed spokesperson of this approach, and he argues that "....cultural materialist theoretical principles are concerned with the problem of understanding the relationship among the parts of sociocultural systems and with the evolution of such relationships, parts and systems." (1979:47). The strategy of cultural materialism is based upon the principle of techno-environmental and techno-economic or demographic determinism (Kohl 1981), and the limitations of this approach have been discussed extensively (Friedman 1974; Leacock 1972). Cultural materialist approaches have questioned the explanatory value of colonization, migration and inherent nature of cultures, and focussed attention on how cultures adapt to their environment. Examples of this theoretical perspective in subsistence studies are MacNeish (1972, 1978), Sanders and Price (1968), Plog (1977), Larson and Michaelson (1990), Bar-Yosef and Belfer-Cohen (1992).

Cultural ecological approaches consider culture as a specific adaptation by humans to a broader environment that also includes other cultures. This form of materialism is derived principally from Steward (1955, 1977). In contrast to cultural materialists, cultural ecologists assign active roles to the values of a culture adapting to its environment (Kohl 1981). Thus, culture becomes the active element responsible for the success of human adaptation to the environment. Prominent examples of ecological

approaches to subsistence research include Ellen (1982), Flannery (1976), Ford (1978), Wetterstrom (1978) and Meadow (1971). Ellen (1982) asserted that the capacity of human populations to survive in a particular environment depends on their ability to harness adequate energy from the resources of a dynamic environment. This can be accomplished through technological development, natural and cultural controls on population size and structure, settlement adaptations and modification of the environment through intensive methods such as agriculture. Recent ecological approaches in subsistence studies include Fritz (1990), Cooke (1992), Hastorf (1990) and Kent (1989).

Economic materialism considers the economy or productive activities of any given society as the intermediary between that culture and natural forces (Kohl 1981). This approach views technology as the principal agent of cultural change, and most studies with an economic materialist approach emphasize the society's technology and exchange networks. This approach differs significantly from ecological materialism, since the focus is on the exchange patterns and technology as opposed to the latter's focus on the interface between culture and environment. An example of a recent subsistence study with such an approach is Wills (1992).

The study of prehistoric subsistence systems of agricultural societies has been the focus of extensive research (Harris and Hillman 1989; Hastorf and Popper 1988; van Zeist and Casperie 1984). Prehistoric diet has become an important issue in these archaeological investigations, and different approaches are taken to address the subsistence systems of past cultures. Traditionally there is a distinction between floral and faunal remains, with paleoethnobotanical and archaeofaunal studies being distinct yet complementing avenues of investigation. In recent decades other avenues of investigation and techniques, such as bone chemistry and residue analysis, have been

utilized to study prehistoric subsistence activities (Ambrose and DeNiro 1987; Price, Schoeninger and Armelagos 1985; Schoeninger, DeNiro and Tauber 1983). This is an encouraging development since the reconstruction of past subsistence systems is complex, and complementing data from different avenues of investigation are necessary for more accurate interpretations.

The goals and approaches of all subsistence studies are similar in that they seek to ascertain how the ancient cultures made a living in terms of obtaining food, consumption and related activities. Common research questions that are addressed include; which plants and animals were eaten regularly, which were preferred, and which were the major components of the diet? Was there any social/gender/age differentiation in food consumption and acquisition? How was food procured? Moreover, subsistence studies, specifically archaeofaunal studies and archaeobotany, require knowledge of the effect that formation processes, particularly taphonomy, have on the archaeological record (Lyman 1982; Shiffer 1983). This issue of context, specifically the predepositional and depositional processes related to botanical remains, is a major concern of this dissertation.

Reconstruction of prehistoric diet is a very common theme of subsistence studies, since understanding human diet is key to comprehending a series of issues related to success and failure of adaptive strategies and subsistence systems, change in subsistence behavior and so on. There are several ways to approach the issue of archaeological reconstruction of diet. One method entails study of the residues of food consumption/processing, which includes the study of plant remains (macro-botanical), animal remains, residues of protein, lipid and blood on tools and containers and phytoliths. The second method of diet reconstruction is the study of human skeletal remains for macro-evidence of nutrition diseases and food stresses. In recent years, bone chemistry has become an important tool for dietary insights. The most common

and widespread methods, however, entail the examination of animal and plant remains recovered from archaeological sites. This dissertation combines the studies of the macro-botanical remains and bone chemistry to investigate subsistence practices during the Late Harappan phase in Gujarat.

Studies of South Asian prehistoric subsistence systems typically adopt a cultural ecological approach (Belcher 1991; Meadow 1991; Ratnagar 1986; Reddy 1991, 1990; Thiebault 1988). However, Weber's (1990) research on Harappan subsistence has more of an environmental focus rather than a socio-cultural or economic focus. In general the importance of subsistence studies to cultural reconstruction is being realized only recently, and subsistence data were rarely recovered from excavations and research in the early and mid 20th century. Faunal and floral remains represent the main corpus of data for subsistence studies in South Asia. Residue analysis, phytolith studies and bone chemistry are rare or absent. At present, macro-botanical remains are scarce from South Asian prehistoric sites, both in terms of quantities recovered and the number of sites in which recovery methods were employed. This scarcity could be an attribute to poor preservation, but it clearly reflects that botanical remains were not considered vital information in the reconstruction of the past. Agricultural processes related to domestication, adoption and intensified production have been interpreted and modeled in South Asian prehistory, despite the dearth in paleoethnobotanical investigations. Recent investigations by Constantini (1987, 1984), Kajale (1988, 1974), Reddy (1990, 1991a, 1991b), Saraswat (1981), Savitri and Vishnu-Mittre (1978), Vishnu-Mittre (1985, 1982), Wagner (1985) and Weber (1990, 1991) are rapidly building up the much needed paleoethnobotanical data set necessary for rigorous research.

The need to expand the prehistoric subsistence data base is only now widely recognized, given the significance of subsistence issues to reconstructing the past. This

dissertation offers a fresh approach to the study of prehistoric subsistence systems, particularly the reconstruction of plant usage, interaction between plants and humans, human behavior in relation to plants, and implications for the interaction between plants and domesticated animals. The strengths of this study lie in the application of new and complementary methods of investigation, so that multiple lines of evidence are available for the interpretation of past subsistence practices. My approach to the study of subsistence system of the Late Harappan of Gujarat also builds on the work of Weber (1990, 1991) who documented the archaeobotanical status of plants (particularly millets) in the Gujarat Harappan subsistence through his intensive study of macro-botanical remains at the site of Rojdi. Taking this initial study of Gujarat Harappan subsistence to the next level of investigation, this dissertation examines human behavior at the sites of Babar Kot and Oriyo Timbo, in terms of plant usage through a combination of paleoethnobotany, ethnoarchaeology and stable isotopic investigations. The next section discusses the goals and pertinent issues related to the study of archaeological plant remains.

Paleoethnobotanical investigations

Archaeological plant remains provide crucial data for economic studies, specifically the subsistence practices of the past cultures. Plant remains provide direct evidence of the association between humans and specific economic activities. Ethnographic studies confirm that plant remains recovered from archaeological sites are indicators of specific human behavior and/or accidental inclusions from the local habitat (Ford 1979, 1985). Since the ancient plant remains are only partially indicative of human activity, their study falls into two disciplines: archaeobotany and paleoethnobotany. The recovery, identification and study of plant remains from archaeological contexts is archaeobotany (Ford 1979:229). The study of plant remains

from archaeological contexts which were cultivated or utilized by humans in ancient times has been defined as paleoethnobotany by Renfrew (1973) and Helbaek (1959). There are many shades of meaning for these two terms, but for the purpose of this dissertation, paleoethnobotany is referred to as the analysis and interpretation of archaeobotanical remains to provide information about the interpretation of the interaction between human populations and plants (Popper and Hastorf 1988:2). By necessity, the first stage of such research is the recovery and identification of archaeobotanical remains. This is usually followed by interpretations which are typically dependent on the questions posed by the researcher.

Since Helbeak (1959) coined the term 'paleoethnobotany', it has become an integral component of anthropological archaeology. Even though it is a part of ethnobiology, paleoethnobotany uses ecological and archaeological approaches (Pearsall 1989). Interpretations elucidate the nature of human-plant relationships as relevant to the archaeological context. The relationships and interactions between humans and plants may take a number of forms, including differential use of plants as fuel, food, fodder, medicines, in rituals, seasonality of availability, human-plant interdependency, and so on. In general the problems addressed by the paleoethnobotanist are often dependent on the overall objectives of the excavations/ research project. The focus of the paleoethnobotanical study varies; for example, a key element of American paleoethnobotany is ecology (Bohrer 1986; Ford 1979), with the interpretation of data focussing on what can be learned about the impact of humans on certain plants and the landscape. European paleoethnobotany however has moved beyond traditional focus on morphology and taxonomy, to cultural interpretation (Ford 1985). Excellent examples of such progress in paleoethnobotany are the research by Hillman (1984) and Jones (1984).

Paleoethnobotany lacks a coherent synthetic theory linking culture and botany, its methods are derived principally from botanical sciences, and its contributions to archaeology are determined by the questions or problems being addressed (Ford 1988). For example, some of the critical questions of human evolution, such as plant domestication and the role of environmental stress, require paleoethnobotanical investigations. Recent paleoethnobotanical research has addressed a ever more diverse range of questions including the identification of crop processing and husbandry (Hastorf 1988; Hillman 1984; Jones 1984; Tremaine 1992), continuity and change in plant subsistence strategies (Weber 1991), the use of dung as fuel (Miller 1984), identification of fodder (Charles 1990; Rasmussen 1993; Wetterstrom 1988), and domestication rates (Hillman and Davies 1990). In addition, paleoethnobotanical studies are of recent beginning to focus on social issues related to food choices, access to resources and ethnic differences (Hastorf 1990). This expanding scope of paleoethnobotany requires developing new methods and theories to provide accurate information about human society from plant remains. This dissertation in one such development in South Asian paleoethnobotany.

A sound methodology for linking archaeologically recovered plant remains to past human agricultural practices is a critical issue for paleoethnobotanical investigations. Of course, this issue is not exclusive to paleoethnobotany. The problem of assigning meaning to the data in archaeological context has been emphasized by Clarke (1973), Schiffer (1976) and Binford (1977, 1981). They all argue that to interpret past human dynamics a strong theoretical orientation, termed respectively 'interpretive theory', 'behavioral archaeology' and 'middle range theory', is necessary. Binford, in particular, contrasts his 'middle-range-theory' (to interpret past human dynamics) with 'general-theory' (the study of processes responsible for change and diversification). It is important to note, however, that the two are not entirely

independent (Clarke 1973). In the context of this dissertation, the ultimate goal of understanding the Gujarat Late Harappan plant usage in the context of the society as a whole may be considered part of general theory. The 'middle-range-theory' issues entail inferences relating to agricultural practices from charred plant remains. The development of such middle-range methodology and its application to the study of Gujarat Late Harappan is the theoretical and methodological theme of this dissertation.

Clarke (1973) distinguishes several sequential tiers of theory within the area addressed by middle range research; predepositional, depositional, post-depositional, retrieval and analytical theory. This dissertation addresses middle range research at each level distinguished by Clarke (1973). Measures are taken to minimize the effects of postdepositional and retrieval problems by taking full account of stratigraphic information, probable biases of preservation, and the development of a rigorous sampling and recovery program. A major objective of the dissertation is to contribute to the study of predepositional and depositional aspects of middle range research. The predepositional aspects entail the study of husbandry practices applied to crops in the fields, and the crop processing sequence after harvest and before use as food, fodder and fuel. The depositional aspects are focussed on the circumstances of preservation by charring of plant remains, either accidentally or through deliberate burning, and the subsequent discard of these remains. The ethnographic crop processing studies contribute to the interpretation and elucidation of predepositional and depositional processes. This is done by explicitly defining specific natural and cultural factors that effect the final archaeologically visible data set. These studies, along with the complementing paleoethnobotanical investigations, contribute to the various aspects of middle range research of the Late Harappan subsistence systems in this dissertation project.

Paleoethnobotanical data includes a variety of plant remains which can be broadly classified as micro-remains (such as the micro-remains pollen grains, spores and phytoliths) and macro-remains (such as seeds, nuts, fibers and wood). This dissertation focuses on the macro-remains, particularly seeds, nuts, and plant parts related to their harvest and processing for human consumption. The deposition and preservation of archaeological seeds is a complex process. All the seeds recovered from archaeological contexts need not necessarily be cultural, since the seeds could have entered the archaeological record through processes unrelated to human activities. Therefore, the context and nature (carbonized or fresh) of the seeds are critical for any paleoethnobotanical investigation. Green (1979) has forcefully argued that the most common means of seed preservation in archaeological contexts is through charring or mineralization, and in most situations uncharred seeds are considered to be recent contaminants. There are several ways by which seeds which are not prehistoric, may end up in archaeological context. As articulated by Keepax (1977:225), there are four distinct sources of contamination: poor excavation techniques, sample collection, and flotation; wind blown contamination of exposed samples; contamination through the flotation apparatus; and in situ contamination through sediment disturbance by natural formation processes. Each one of these concerns was given serious consideration in the paleoethnobotanical investigations of this dissertation.

There are some serious constraints on paleoethnobotanical investigations, since there are several processes that effect the representativeness of recovered archaeological plant macro-remains. First, the botanical record, particularly for seeds, is a highly biased, often incomplete reflection of the past, since only a small fraction of the seeds used are preserved, and an even smaller fraction are recovered. The physical characteristics of a plant also effect its preservation. For example, it is generally accepted that big seeded plants produce a smaller number of seeds, and therefore they

are less likely to be preserved in large numbers. Conversely, small seeded plants produce larger numbers of seeds, thus increasing the number of seeds likely to enter and preserve in the archaeological record. These conditions have to taken into consideration in paleoethnobotanical investigations and interpretations.

Carbonization of the plant seeds is considered by paleoethnobotanists to be the most reliable field indication of antiquity. Therefore, only charred seeds are ordinarily considered to be of prehistoric age. However, it is important to note that seeds can be carbonized through natural fires. An effective and easy method to control for this bias entails examining non-archaeological samples near the site for carbonized seeds. If there are no charred seeds recovered from these sediments (as it was in the case for sites examined in this dissertation), one can assume that all charred seeds recovered at the sites are prehistoric or at least pre-modern in age.

To reconstruct the relationship between plants and humans, and to elucidate associated human behavior, it is important to determine the processes by which the seeds became carbonized prehistorically. Discounting natural fires, there are several ways in which carbonization would occur, of which intentional burning (as fuel) or chance or accidental burning during processing (of food grains) are most common. The decipherment of these processes is key to the understanding of the subsistence processes in play prehistorically.

An obvious limitation of paleoethnobotanical studies is the ability to reconstruct patterns and processes related to subsistence activities solely based on archaeobotanical data. For example, questions related to the cultivation of certain crops, the presence of distinct processing stages at the site, and consumption of a particular plant as human food by the inhabitants are rarely resolved only with archaeobotanical data. Other avenues of investigation are needed to better interpret and elucidate such processes and

activities archaeologically. One such avenue specifically chosen in this dissertation to answer questions related to the economic status and use of millet crops during the Gujarat Late Harappan, is the ethnoarchaeological study of millet crop processing.

Ethnographic crop processing studies

An important goal of paleoethnobotany is to use the recovered archaeobotanical plant remains to identify activities related to crop production, processing, and consumption. Dennell (1972, 1974, 1976), Hillman (1981, 1984) and Jones (1983, 1987) have each made seminal contributions to these issues. Their individual approaches and methods of investigation are distinct, and specific models identifying plant processing in the archaeological record first came from British paleoethnobotanists.

Dennell (1979) argued that food production rather than food consumption can be modeled from paleoethnobotanical data, mainly because plant resources are preserved in contexts of food production and processing more commonly than contexts of consumption. The effect of crop processing activities, and therefore of archaeological context, on the composition of archaeobotanical samples must be taken into account before a prehistoric crop economy is reconstructed (Dennell 1972). Dennell (1972) constructed a general model of crop processing based on his personal knowledge and observations of grain processing in the Old World, and he defined a sequence of processing steps and probable compositions of grain parts and wild seeds generated at each step. This theoretical model of crop processing and deposition along with other archaeological data focussing on well-defined contexts to address specific questions was used to identify botanical samples from specific cultural contexts (Dennell 1974, 1976, 1978).

Since this pioneering research, Hillman (1984) and Jones (1984) developed

more thorough and predictive models of specific processing activities through detailed ethnographic studies of traditional crop processing in the Old World. These crop processing studies deduce details of farming practices, such a harvesting and processing of crops, based on the composition of crop processing residues. Hillman (1981) argues that there are relatively few efficient methods of processing a crop available to non-mechanized farmers; in other words, a crop can be processed in only a limited number of ways. Hillman (1984) and Jones (1981, 1983) have also argued that husbandry practices (such as the choice of soil, tilling methods, sowing time, and irrigation) have a distinct effect on what weeds grow in the cultivated fields, and these processes are potentially detectable through archaeobotanical analysis of the weed seeds. Hillman (1980) and Jones (1981, 1984) define specific stages and contexts in the processing sequence of wheat, barley and legumes through flow charts generated from studies of processing, disposal and accidental charring. They conclude that specific ethnographic sample compositions result from a particular crop processing stage. Thus, given an archaeological sample of plant remains similar to documented ethnographic samples, it is inferred that these archaeological remains were the product of essentially similar crop processing methods. Predicted stages then can be matched to similar contexts in the archaeological record on the basis of plant frequencies. So, with adequate sampling for macrobotanical remains, investigators can identify the past activity at particular locations (Hillman 1981).

The main problem with such ethnographic studies is one of inference. To make statements about past crop processing and crop husbandry based on the charred archaeobotanical remains, a link between activities and the material observable must be made. This can be done by observing activities in the present that result in specific archaeologically visible patterns. There are, undoubtedly, problems with analogies

between the past and present, since similarity between the present and the past in one respect or context does not necessarily imply it in another (Binford 1981; Hodder 1982). Therefore, methods should be sought at the analytical level to identify patterns in the data and evaluate their significance. Then interpretive theory comes into play in assigning meaning to these patterns (using ethnographic modeling), and subsequently evaluating the relative merits of a range of possible interpretations. The direct analogy problem is evident in uniformitarian arguments about people, however, in ethnographic studies of crop processing, such assumptions are made about plants and their behavior under defined physical conditions and restraints. Such a relationship is causal and relevant (Binford 1981), and, using Hodder's (1982) terms, is 'relational' rather than 'formal'. In any case, it is crucial that analogies take account of the context in which they are applicable (Hillman 1981; Hodder 1982).

Ethnographic studies of crop processing activities have been used to make inferences about the archaeological use of specific crops (Hillman 1984; Jones 1983, 1987), and to build 'cause and effect' models for archaeological interpretation. The principle behind these studies is that a crop is processed through a number of stages before it is consumed, and that each step of crop husbandry and grain processing has a measurable effect on the composition of crop products and by-products. Depending on the type of crop, there are a set number of stages that it passes through. For example, all crops have to be threshed and winnowed, and the number of threshings and winnowings vary, as do the types of threshing and winnowing. There are limitations in the previous predictive modeling studies (Hillman 1984; Jones 1984), since they are applicable only to wheats and barley; No such models have been developed for millet cultivation. Application of existing models to other crops (such as millets or corn) is not possible since the basic premises of the models is specific to the morphology of wheat and barley crops and the necessary processing methods and sequences. Additionally,

the ethnographic studies of Hillman (1984) and Jones (1984) were in Turkey and Greece, both very different environmentally and culturally from Gujarat, India, and the crop processing stages of India are known to be different from the Near East. Therefore, it was necessary to conduct a pioneering ethnographic study of millet crop processing, to enable modeling for archaeological contexts in India.

The ethnographic crop processing studies of this dissertation were not conducted in isolation from the works of Hillman (1984) and Jones (1984); instead, they were developed and structured to complement previous studies. The main objective of my ethnographic study was to discern the millet crop processing sequences, isolate variables which distinguish different stages, and to model for archaeological interpretations. An additional objective was to identify whether millets are processed differently depending on whether they are grown only as human food, both as human food and animal fodder, or when grown only as fodder. The principle behind these studies is that any distinction in processing (for the three different purposes) would have a measurable effect on the composition of crop products and byproducts. It was therefore necessary to isolate the variables which distinguish crop processing stages when millets can be grown for the three different purposes: food, fodder or both. My detailed ethnographic research was designed to quantitatively discriminate the variables that correlate the cultivation of millets with their ultimate use. The processing pathways of summer crops grown for different purposes were examined and samples collected from each processing stage for analysis. The models generated were then testable archaeologically, if a sufficient sample of analogous plant materials are recovered through flotation.

Two main ethnographic studies of millet crop processing in India were conducted in this dissertation; summer cultivation and 'Opportunistic' cultivation.

Summer cultivation of millets (Pennisetum typhoides and Sorghum bicolor) was studied in Gujarat, India, which is also the locale of the Late Harappan sites investigated. Traditional cultivation and processing of millet crops is still practiced in this region, and Gujarat offered the ideal venue to conduct such a study of crop husbandry and processing.

The other ethnographic study in this dissertation involved the exploitation of a floodplain in South India through a specific form of agricultural practice termed here as 'Opportunistic' cultivation- an extensive form of cultivation exploiting the annual flooding of the river. Extensive 'Opportunistic' cultivation also could be an important economic activity elsewhere (such as prehistoric Egypt and Europe), where ancient civilizations focussed along the river courses. The study of such cultivation for archaeological interpretations is scarce but very important. From time immemorial river floodplains have been an attractive environment for human exploitation, particularly for agricultural and pastoral pursuits. Well known examples of such occupancy, prehistoric and historic, range from settlement occupation along the Mississippi and the Amazon in the New World, to the Danube, Nile, Tigris, Euphrates, Indus and Huang Ho in the Old World. River floodplains are dynamic and each is unique in its nature. These riverine systems have been manipulated for agricultural activities and quite often human settlement patterns have been strongly influenced by these river systems and their floodplains.

The Indus civilization was set around two major river systems and their floodplains provided vast areas for grazing and agriculture. The Indus Valley Tradition as defined by Shaffer (1991) includes all human adaptations in the Greater Indus Region from around 6500 B.C to 1500 B.C.. The diversity of the subsistence base and resource variability with the potential for surplus production was one of the preconditions needed for the successful development of integration and urbanization of

the area (Kenoyer 1991). The fertile floodplains of the region were highly productive without massive irrigation systems. In the light of this, the study of the 'Opportunistic' Cultivation and the understanding of the dynamics of its economy are valuable for furthering our understanding of the growth of the Indus Valley Tradition.

CASE FOR AN INTEGRATED APPROACH

This dissertation examines the economic importance and use of millets in the Late Harappan of Gujarat, India. Of particular importance is the elucidation of two issues: (1) whether millet crops were cultivated by the occupants of Oriyo Timbo and Babar Kot, or were they traded and brought into the settlement; (2) the ultimate use of the millets (regardless of whether they are imported or cultivated) either as human food, animal fodder, or a combination of both. To successfully address these research questions, it is essential to integrate several avenues of investigation. Since the current understanding of Harappan subsistence regime in Gujarat is primarily conjectural the use of multiple lines of evidence has considerable potential to strongly contribute to understanding of the processes and character of the Harappan subsistence systems. Paleoethnobotanical investigations are certainly necessary to address these research questions. However, given paleoethnobotanical limitations and the need to address predepositional and depositional aspects of middle range research, ethnographic crop processing studies were also needed. Thus, integrating these two complementing approaches to subsistence studies provides for robust interpretations of the archaeobotanical data.

Crop processing studies and paleoethnobotany cannot with absolute certainty resolve the question of whether millets were used as fodder. Carbon isotope analysis of animal bones was chosen in this dissertation to complement these two approaches. The

basis of carbon isotope analysis rests on the scientific determinate that there are three types of photosynthetic pathways in plants (C3, C4 and CAM) and there are two stable carbon isotopes in the biosphere which are taken up differentially by all living creatures (Carbon 12 and Carbon 13). The ratios of these two stable isotopes of carbon in animal bone collagen have been used to determine the relative contribution of C4 plants (such as maize and millets) versus C3 plants (such as wheat and barley) to the diet of the consumer (Deniro and Epstein 1978; van der Merwe 1982). If millets were used as a major source of animal fodder, then the higher proportion of C4 plants in the animal diet would be reflected in the carbon isotope signature of the animal bone collagen. Thus, carbon isotope analysis can be used to determine the use of millets/C4 plants as animal fodder. This analysis cannot distinguish, however, between the use of millet grains versus millet crop residues as animal fodder. However, this distinction is important because the use of millet grain for animal fodder would indicate that the crops were primarily grown for animals, whereas using only the millet residues for fodder implies that the crops were grown for both human and animal consumption. These differences significantly affect interpretation of past subsistence economies. Crop processing studies provide a viable complementary line of evidence to identify this distinction.

For a thorough and comprehensive investigation of the problems related to food and fodder, the quantitative results from the three analytical methods need to be evaluated and integrated. For example, since variables related to seasonality and differential feeding of grains versus crop by-products cannot be identified and defined by carbon isotope analysis, and their elucidation is essential for the interpretation of past economies, it is necessary to complement carbon isotope analysis with other lines of evidence. Thus, the three lines of evidence (ethnographic studies of crop processing, paleoethnobotany and carbon isotope analysis) are intertwined to offer robust

interpretations of the Late Harappan subsistence.

With respect to the study of Harappan subsistence economy in Gujarat, the exact proportion of millets in animal diets is not as critical as relative long term changes in the dependence on different fodders, particularly millets versus previously utilized wild fodders. An increased emphasis on millets as fodder during the Late Harappan of Gujarat may indicate the emergence of a specialized subsistence system, with animal husbandry as an important and critical variable, perhaps with parallels to present day Gujarat (Reddy 1990, 1991). Such a change in subsistence economics, entailing specialized food production and intensification, could have far reaching implications for the Late Harappan period in Gujarat.

This project is designed to define the economic role and use of these summer crops, particularly to determine if there was increased cultivation of plants particularly for animal fodder in the Late Harappan Gujarat, which would have been important in animal husbandry. Resolution of this issue will aid elucidation of the potentially complex interplay between pastoralism and agriculture during Late Harappan times. An increased focus on fodder cultivation implies a more specialized subsistence procurement, and in this case a shift from a prior non-specialized procurement system. The project investigates this issue through the complementary methods of ethnographic crop processing studies in India, archaeobotanical analysis of plant remains from the Late Harappan sites of Babar Kot and Oriyo Timbo in Gujarat, and carbon isotope analysis of animal bones (specifically cattle) from Late Harappan sites. The next chapter presents the methods and basic results of the ethnographic crop studies of millets conducted in India.

CHAPTER 4
ETHNOGRAPHIC CROP PROCESSING STUDIES

INTRODUCTION

A sound methodology linking archaeologically recovered plant remains to past human agricultural activities is essential for the study of agricultural practices and subsistence systems. This chapter presents an account of the ethnoarchaeological field work and observations related to crop processing activities. The chapter is structured to address the two seasons of fieldwork, summer cultivation and winter 'Opportunistic' cultivation, as case studies for archaeological interpretation. Summer cultivation is presented first, with a detailed discussion of the crop processing activities relevant to this study. The second half of the chapter examines 'Opportunistic' cultivation and its associated crop processing activities. The emphasis of each discussion is on archaeologically relevant and important contexts, activities and processes.

The two geographically distinct study areas in India were selected to facilitate examination of seasonal and geographical variations in crop processing (Figure 4-1). In order to successfully model for a range of archaeological situations and to build predictive models that can be adjusted and applied globally, ethnographic data should not be too specific. Therefore, it was imperative to collect data from two geographically and seasonally different loci: winter flood plain cultivation in the modern state of Andhra Pradesh (South India) and summer monsoon cultivation in the modern state of Gujarat (Western India) (Figure 4-1). Three factors determined the selection of these particular study areas. The two agricultural systems were selected because they presented ideal logistics for research and study. In addition, the two farming systems are significantly different in terms of economic strategy, yet they both

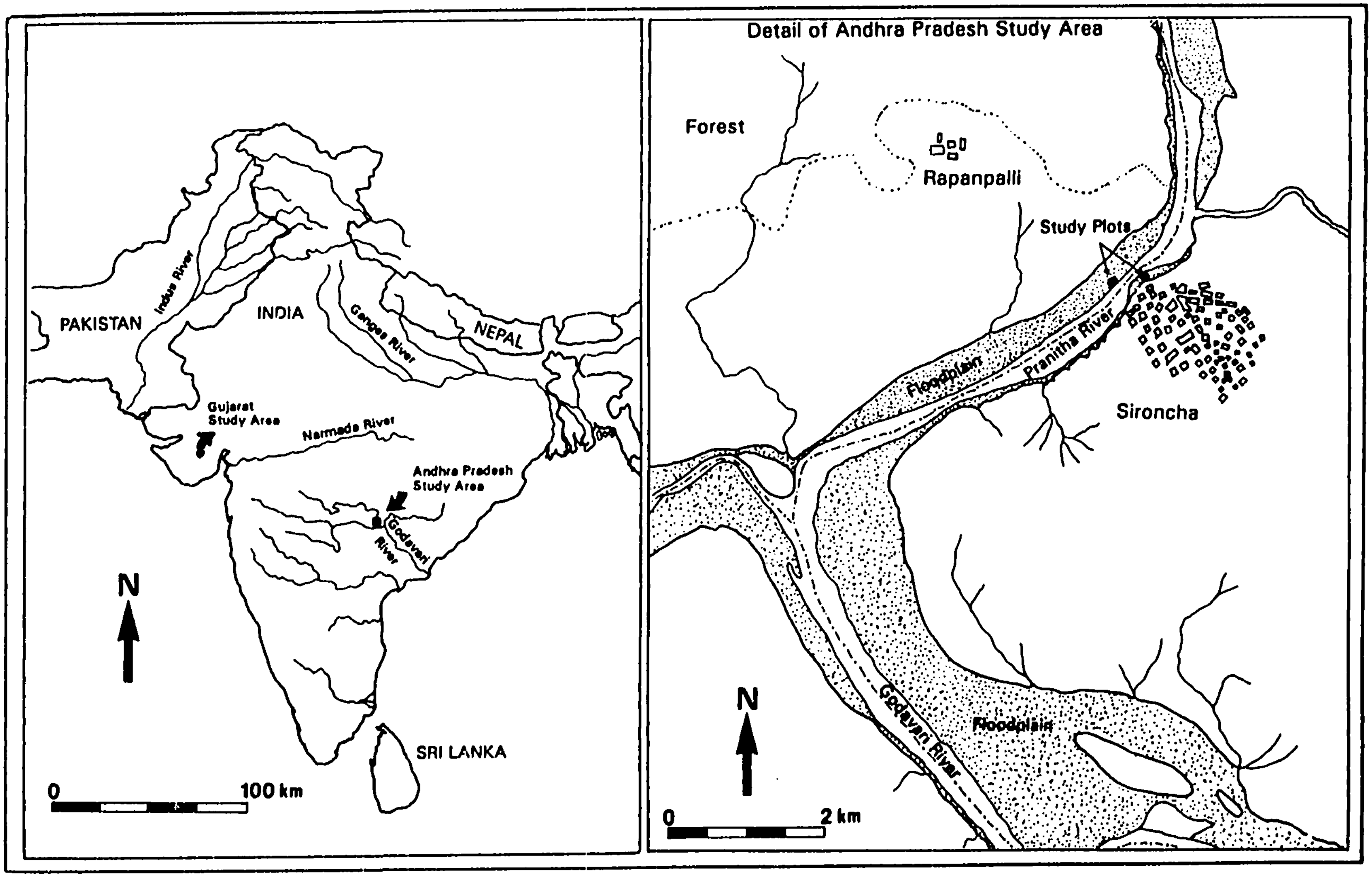


Figure 4-1. Map of India Showing the Study Areas

have relevance to Harappan subsistence economy. Winter 'Opportunistic' cultivation is an extensive form of economy, while the summer monsoonal cultivation is an intensive economic activity. Potentially both systems of subsistence procurement could have had related counterparts in the Harappan times; for example 'Opportunistic' cultivation along all the major river systems and summer cultivation in Gujarat and Punjab.

The third and most important factor which determined the selection of the two study areas of Andhra Pradesh 'Opportunistic' cultivation and Gujarat summer cultivation entails the types of crops involved. 'Opportunistic' cultivation involves the cultivation of Panicum miliare, while summer cultivation is primarily involved with Sorghum bicolor and Pennisetum typhoides. These crops are distinct in their morphological characteristics relevant to crop processing, specifically harvesting. It is proposed here that the morphology of the crop plant determines the type of harvest technique that can be used. In plant crops such as Sorghum bicolor, Pennisetum typhoides and Eleucine, the stalks/stems are thick and only one to three plants at a time can be cut. This automatically provides for selection against most weeds being included in the harvested materials, because when only one to three stalks are being cut, the harvester can select only the crop plant stalks to cut. In addition, the seeds bearing 'heads' (panicles) are compact and bigger in size in these crop plants. Therefore, they are often separated from the stalks after harvest and only the separated seed bearing heads are subsequently processed. Furthermore, harvesting can also be done by cutting off only the panicles (the seed bearing earheads). This harvesting procedure leaves the rest of the plant standing, and also selects out the weeds. These crops have been grouped as Type A crops (Reddy 1991), and the harvest method termed Type I harvest.

In contrast, crops such as Panicum miliare and Setaria spp do not have compact and distinct seed bearing panicles, and their stalks are relatively thin. As a result of the

slender stalks/stem, these plants are harvested by gathering a large number of plants together while cutting (Figure 4-2). This makes selection against weeds growing in the field among the crops difficult and often too time consuming. Therefore, weeds get incorporated into the harvested materials and then processed out in the subsequent stages of processing. The separation of seeds from the plant therefore requires the harvest of the entire plant and the subsequent separation of crop grain through various processes. These crops are grouped as Type B crops and their harvest technique is termed Type II harvest.

Therefore, the critical difference between the two crops and their harvest methods is in the inclusion of weeds into the harvested material. This is a significant variable because weeds play an important role as indicators of various processing stages (Hillman 1984; Jones 1987). In Type A crops harvested in method I, there are very few to almost no weeds in the subsequent stages, since they were not initially included in the harvested materials. In the second harvest method (Type II), the weeds are included at harvest because they cannot be selected out without considerable effort on the part of the harvester. Figure 4-3 shows this process and the ramifications of the harvesting techniques. These two distinct situations have great implications for archaeological contexts and interpretations related to crop processing. To model the processing pathways of both the crop types (Type A and Type B), the harvest methods of each were studied in Gujarat and Andhra Pradesh.

SUMMER CULTIVATION (Type A crop cultivation)

Geographical Setting

A season of the ethnographic crop processing studies was conducted in northwest India, in the modern state of Gujarat which is approximately coterminous



Figure 4-2. Type II Harvest Method of Type B Crops

Type A Crops: *Sorghum bicolor*, *Pennisetum typhoides*
Type B Crops: *Panicum miliare*, *Setaria tomentosa*

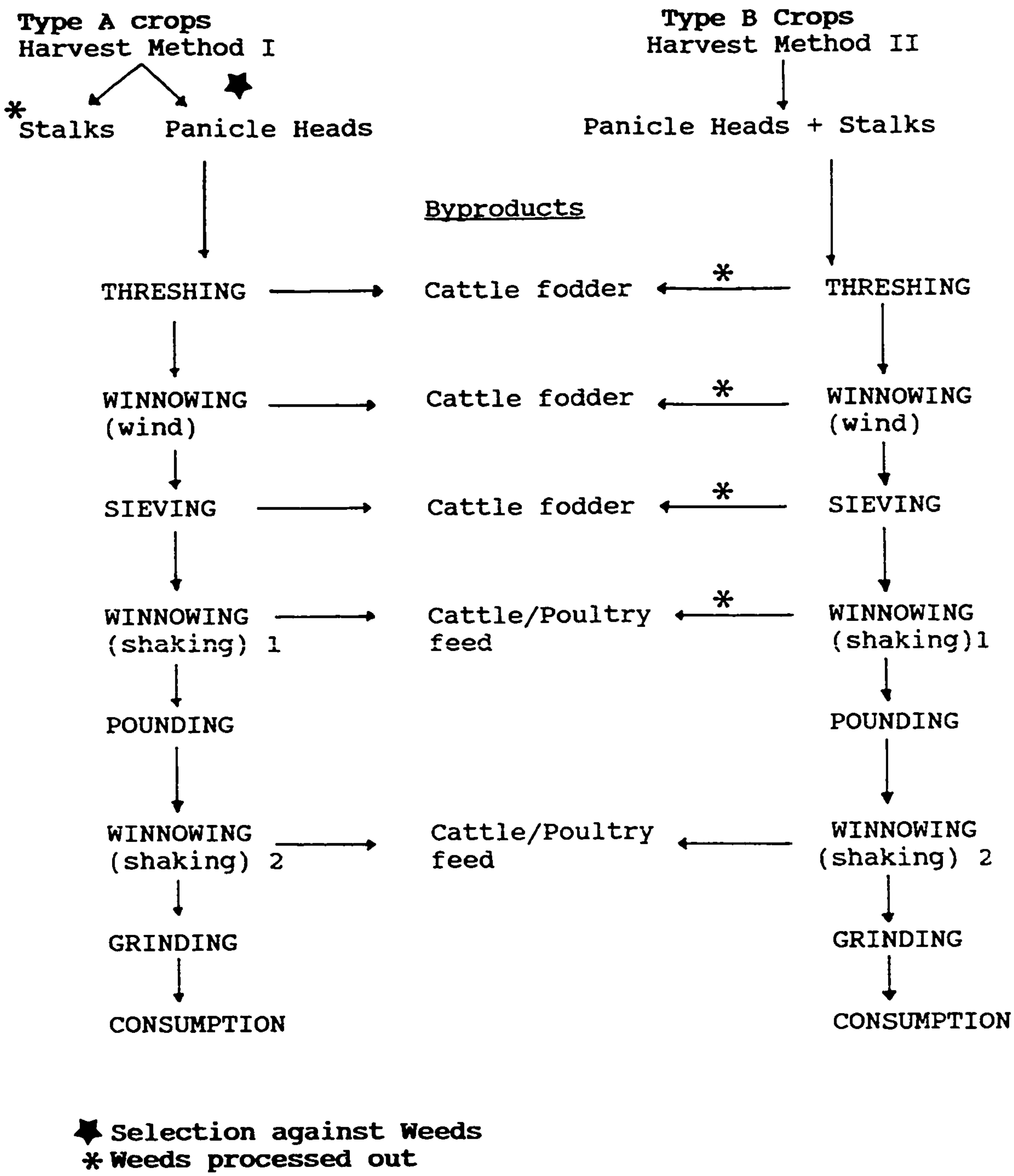


Figure 4-3. Crop Processing Pathways: Type A and Type B Crops

with the southern region of Harappan culture (Possehl 1980:18). The study area is located in a peninsular region called Saurashtra. This area is rich in Harappan sites of varying sizes and types. The ethnographic study was done in the vicinity of the Late Harappan site of Babar Kot. The soils in the area are black cotton soils which have high water retaining capacity. The rainfall is low in the area, falling almost exclusively in the monsoon seasons. An average of 60cm of precipitation per year is common in Gujarat; the monsoons are often poor, thereby bringing very little moisture. There are three distinct seasons in the region; the hot summer months are in March, April and May, the monsoon season in June to September, and winter from October to February. The ethnographic study was done in the months of September through December, since the harvest season spans from late October through November.

Economy of Study Area

Land use in the study area is similar to the rest of the modern state of Gujarat. Dry farming is the most common subsistence activity in this region. The major agricultural season is the 'kharif' monsoon season, which involves sowing with the first monsoonal showers in the months of June or July, and harvesting in October-November. Winter cultivation occurs only with well irrigation, and only on selected farmsteads. The crops cultivated during the two agricultural seasons are distinct. 'Millets' which are drought resistant crops are cultivated in the monsoonal season, while wheat is cultivated in the winter with the aid of irrigation. Occasionally Sorghum bicolor and Pennisetum typhoides are cultivated in the winter months with the use of irrigation. However, it is most often the case that these millets are hybrids or/and cultivated essentially for green fodder. In recent times there has been a persistent warm drought condition in Saurashtra, and even the winter months have been warm enough to successfully cultivate millets. The monsoons have failed repeatedly in very

localized areas, and often there is minimal success of cultivation in these areas. Usually when the crops fail to seed well, they are ultimately used as fodder. Interviews with farmers were conducted to gather ethnohistorical information about whether this present pattern of rainfall possibly occurred earlier. However, the farmers who were interviewed strongly assert that the failure of monsoons is only an event of the late 20th century.

Problem Orientation

In this project, summer cultivation of millets in Gujarat was studied to: provide the regional perspective on agricultural systems and crop processing studies for the Harappan period; study the cultivation in a river plain where there are weeds comparable to archaeological situations; study the crop processing of Type A crops such as Sorghum bicolor and Pennisetum typhoides, and lastly to have geographical and seasonal variation. The specific location of the study area was selected because it is in close proximity to the Late Harappan site of Babar Kot which facilitates archaeological interpretations since the soil, geology and water variables are comparable. On the basis of extant, admittedly scant evidence, scholars have reasonably argued that the development in South Asia of summer, rain fed, 'millet' based agriculture took place largely on the eastern and southern margins of the Indus Valley. This occurred during the Harappan period in areas where monsoon rainfall was sufficient to support the dry farming of these hardy, warmth loving cereals. Therefore, Gujarat provided the ideal area to conduct ethnographic studies due to the Harappan tradition present in the region and the specific geographical location, thereby ensuring that the ethnographic study area and relevant archeological sites are in a similar environmental zone.

Field Methodology

The objective of this study was essentially to develop research models and methodology through ethnographic observations and data analysis to facilitate stronger and more reliable interpretations of archaeobotanical materials. The modern agriculture of Gujarat is characterized by a reliance upon dry farming with eighty five percent of the agriculture being rainfed (Patel 1977). The great majority of crop production occurs in the kharif (summer) monsoon season, in contrast to rabi (winter) production. The main crops grown in the area are Pennisetum typhoides and Sorghum bicolor. Pennisetum typhoides is cultivated under more acreage than any other crop, mainly because of its short maturation period. Sorghum bicolor however, replaces Pennisetum typhoides as the most popular food grain in South Gujarat. It is also an excellent fodder crop for cattle (Patel 1977). Aspects of cultivation such as land preparation, sowing pattern, plant spacing, harvest timing, harvesting methods, crop processing at the field and in houses, and storage areas were studied to identify distinctive variables at each step.

The ethnographic crop processing fieldwork of summer cultivation took place in the settled village of Babar Kot in the Bhavnagar District of the modern state of Gujarat (Figure 2-2, 4-1). The farmer, whose farm and crops were studied, practiced traditional agriculture with no use of mechanization for processing the crops grown on his land. This particular locale was chosen for the study because of its proximity to the Late Harappan site of Babar Kot, and also because millets are the principal summer crops in this general region. Gujarat, the region of India with a high density of Late Harappan sites, is also the locale where the archaeobotanical samples have been collected, and it also has the best represented pastoral/agriculture complementarity in Indian subsistence economies.

Based on ethnographic studies in Greece, Jones (1987: 44) suggested that there

are 14 processing stages for free-threshing cereals and pulses. This project was designed to examine whether these 14 stages or other stages are applicable to millet processing. During the fieldwork, emphasis was particularly placed on documenting the cultivation of millets and their ultimate use, and the research was designed to quantitatively discriminate the variables that correlate the cultivation and processing of millets with their ultimate use.

Two millet crops were chosen for study, those of Sorghum bicolor (Jowar) and Pennisetum typhoides (Bajri). These crops were chosen to complement the study of Panicum miliare in Andhra Pradesh since the former crops are classified as Type A crops while the latter is a Type B crop (Reddy 1991). The selection of the crops was also determined by the availability of such fields for study.

Before the harvest, interviews were conducted over a series of days. These interviews with the farmers included gathering information regarding the crop cultivation, selection of crops for cultivation, preparation of fields, details of the actual process of sowing for different crops during different seasons, etc. Such interviewing is needed for the successful interpretation of prehistoric agriculture following the analysis of the data.

Upon completion of the interviewing, different weeds associated with the millet fields were collected. The collection was facilitated by the farmer, whose knowledge of such associations was extensive. It was important to collect these weeds, in order to have a comparative collection during the analysis of the harvested samples of products and byproducts. It is assumed that the weeds associated with the millet fields will be the ones which will be indicative of different products and byproducts of different stages of crop processing. Such weeds were also collected the previous year and processed for their carbon isotopic signatures to provide insight on the nature of the environment.

The majority of the weeds were C3 plants, which therefore will not be confused with the C4 signature of the millets.

After the weeds in the millet fields were compiled into a comparative collection in September before the crop harvest, study plots were selected in the fields of Pennisetum typhoides and Sorghum bicolor. Three plots of 5 X 5 meters were selected in each of these two crop fields. The selection of the plots was based on the following criteria:

1) Distance to water source: Closer and Further.

2) Distance to cattle shed: Closer and Further.

3) Distance from field of another crop: Closer and Further.

4) Degree of isolation within the field: High and Low.

5) Proximity to a pathway: Closer and Further.

These above criteria may significantly effect the ratio of crop plants versus weed plants, and controlling for these variables will be critical during the analysis and interpretation. Between the three study plots, all the variables of the five criteria were fulfilled.

The 5 X 5 meter squares were laid out in the field using triangulation (Figure 4-4). Long stakes were used to demarcate the study plots, because of the height of the plants. Due to the nature of the area, a pace map was made showing all the activity areas related to cattle keeping, goat keeping, domestic area, field areas of various crops, and weed patches. Irrigation channels, when present, were carefully mapped.

Before and after each of these processing stages, weights of the products and byproducts were recorded, and then samples were taken from each of them. An attempt was made to take a minimum of 15% of the weight for a sample. While taking the sample, careful attention was paid to take a homogeneous sample representative of the

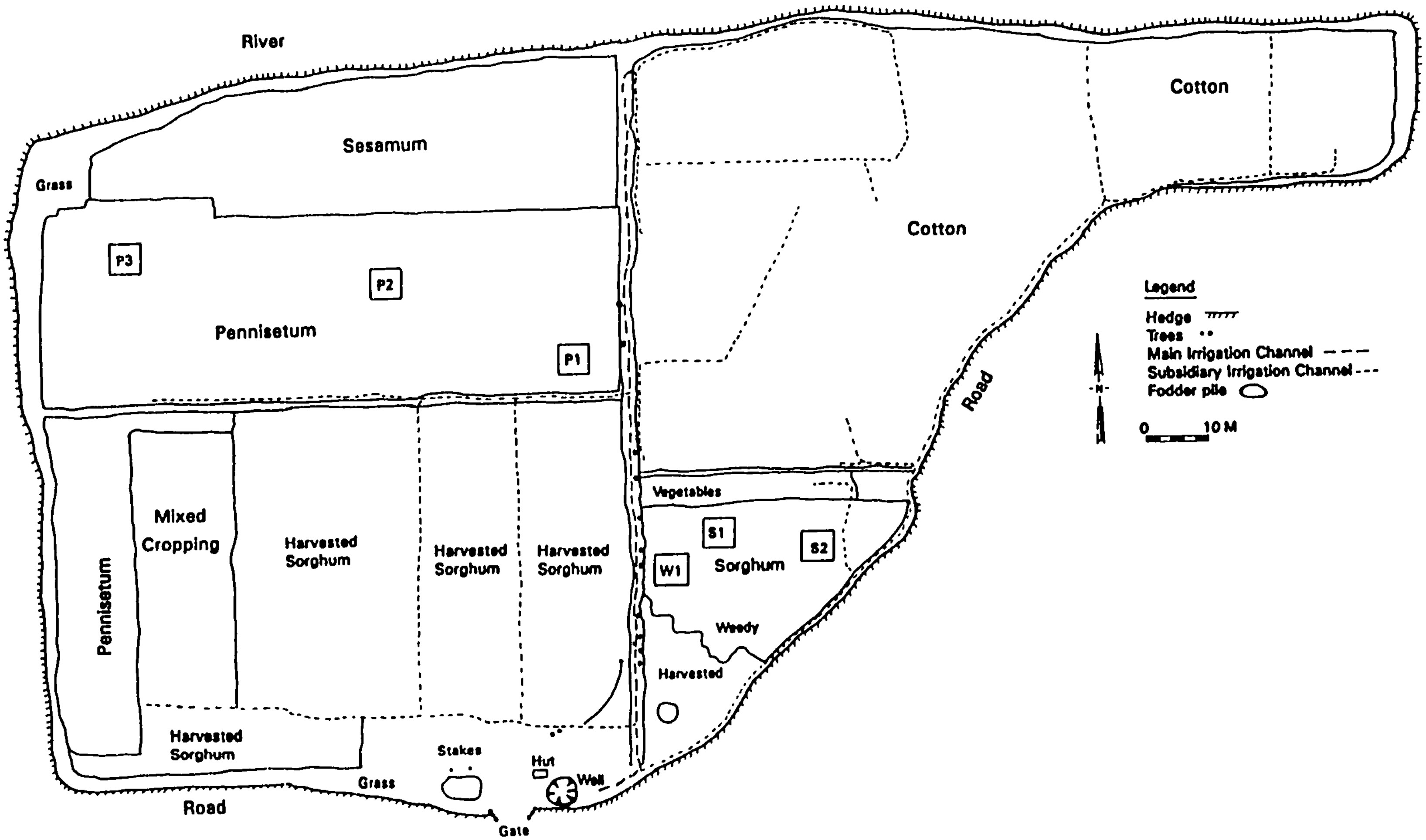


Figure 4-4. Babar Kot Summer Cultivation Study Plots

whole product or byproduct. The uses of each byproduct was noted as the processing was being done.

Of the three plots laid in the Sorghum bicolor field, one plot was very weedy, the predominant weed being Setaria tomentosa. This plot was studied as a distinct plot, since it can be used as an example of wild plant processing for food and/or fodder. The processing done for this plot was similar to that done to Sorghum bicolor and Pennisetum typhoides, with Setaria tomentosa being selected as the final end product. It is a small seeded annual grass that grows wild in Gujarat and is an attractive animal fodder. The study plot of this plant was at the edge of the Sorghum bicolor field where the weed grew wild and took over the area since there were very few Sorghum bicolor plants.

Botany of the Crops

Both Pennisetum typhoides and Sorghum bicolor are tropical grasses and their seeds are similar in that they can be viewed as 'naked' seeds. They are not enclosed in a hard binding seed husk and this has a significant quantifiable difference with respect to processing of the grain for consumption. Pennisetum typhoides is a robust annual grass about 1.5 to 3 m tall with solid stems about 1 to 2 cms in diameter (Rachie and Majmudar 1980) (Figure 4-5). The leaves are long slender and hairy. The plant has a deep root system which helps it survive in drought situations. The seeds are borne on inflorescence heads which are compact, unbranched and cylindrical. The rachis is straight and about 8-9mm thick, and bears the spikelets on an involucre and rachilla. Usually there are an average of 1600 spikelets per panicle head. Each spikelet consists of a short lower glume and a inner longer one. It also has two flowers, one of which is fertile, and occasionally both are fertile and seed bearing. The lemma and palea of the flower do not clasp the caryopsis which threshes free (Rachie and Majmudar 1980).

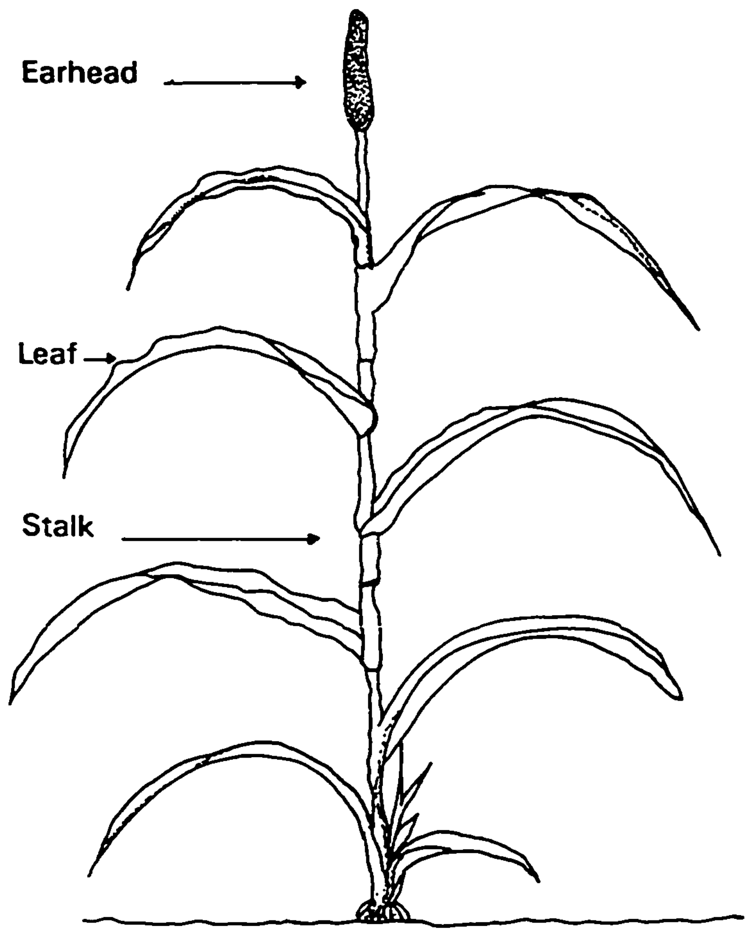


Figure 4-5. Pennisetum typhoides Plant

The caryopsis or seeds are large in size. The elements of the plant that occur in the different crop processing stages are the inflorescence heads with and without grain, rachis fragments, spikelets with and without seeds, grains with glumes and grain without glumes. Pennisetum typhoides mostly grown as a rain fed monsoon weather crop, however to a limited extent it is also grown as an irrigated hot weather crop in central and south India.

The Sorghum bicolor crop plant is similar in that the plant is an annual, and has an erect solid stem supported by a profusely branched adventitious root system (Figure 4-6). The stem bears the compact inflorescence head at the tip. It is a more or less compact panicle with an axis or rachis of variable length (Cobley 1956). The spikelets of Sorghum bicolor occur in pairs on the rachis on the tips of branched stiff branchlets. Of the two spikelets the sessile one produces the grain. It has two glumes and contains two flowers of which only one bears the seed. The maturity of the head starts at the apex of the cylindrical cone and continues down. The caryopsis is rounded and varies in shape and size, and it comes lose of the palea and lemma without much threshing. The plant parts and seed parts that are recovered in the processing stages are similar to those recovered for Pennisetum typhoides.

Sowing

Sowing of both Pennisetum typhoides and Sorghum bicolor is done in the monsoon month of June during the rains. For a week before sowing, the field is ploughed with a wooden plough using two bullocks. Dung is often mixed into the field at this time. There is no irrigation during sowing, since there are rains during that time. Before sowing, fertilizer is put into the furrows. Using two bullocks with a three pipe structure attached to them like a plough, sowing is done as a one day event for each

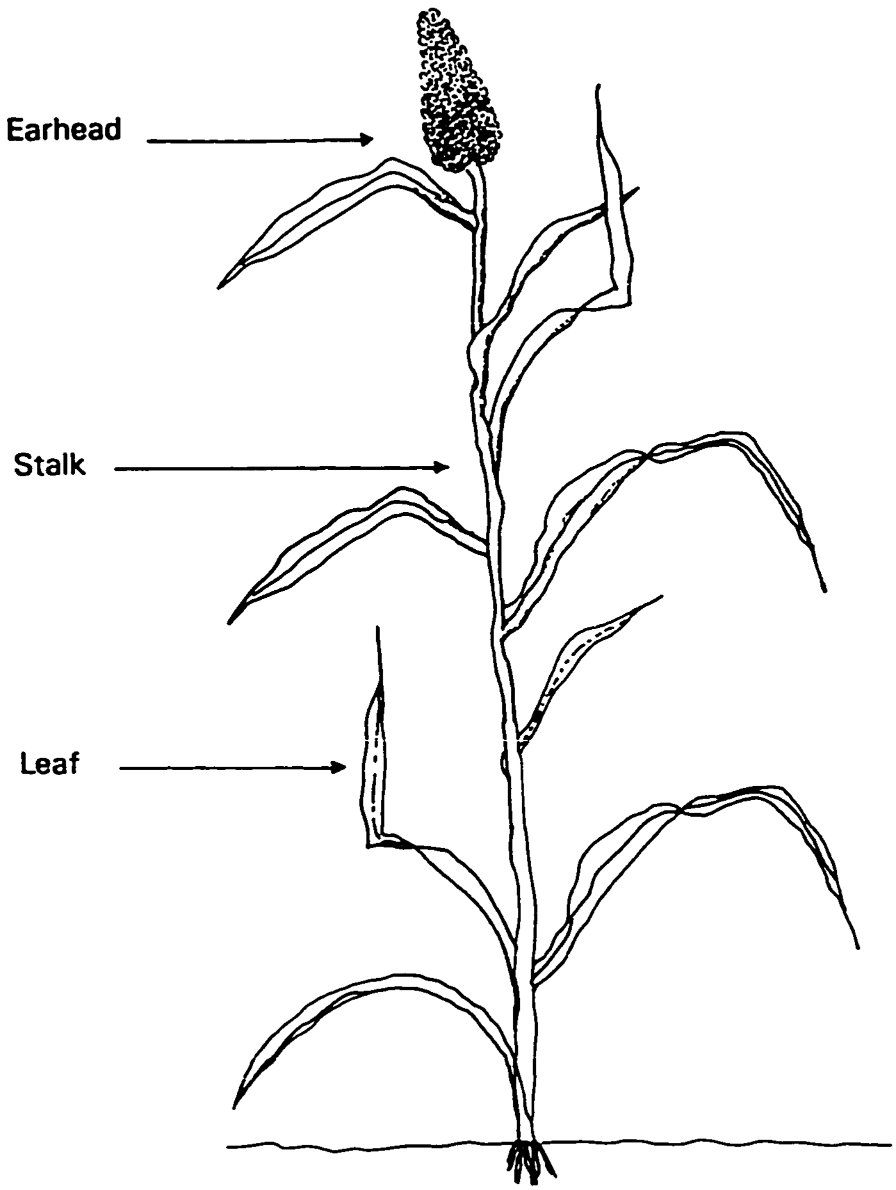


Figure 4-6. Sorghum bicolor Plant

field. The seeds drop out of the three pipes, and the spacing of the plants is about 6-8 inches apart. If the spacing is any closer, the inflorescence head is quite small. Ordinarily, irrigation is not needed if the monsoons are good, but in recent decades there has been a decrease in the quantity of rainfall and success of the monsoons. Therefore, farmers are often forced to use well irrigation about once every five days. When there is no well available then obviously no irrigation is done. The maturation of these crops is simultaneous, because the sowing is a one or two day event. When the land holding is large, then the sowing is done in lots so that the harvest times do not coincide too much, however, the lots are quite close to one another. The farm studied was approximately 5.5 acres in size.

Harvesting

Harvesting and crop processing of the study plots was done in the same manner as the farmers process their own crop. Sorghum bicolor and Pennisetum typhoides are Type A crops (Figure 4-7), therefore harvesting is most commonly done by selecting out the weeds while cutting, since only a few individual plants are cut at one time. When labor is available in cases of large family holdings or richer landowners, often enough labor is employed to first separate the heads of the crops from the stalk in the field itself. The inflorescence heads are processed for grain, and then later the stalks are cut down for fodder. In this case there is very little weed contamination in the crop processing, since they are selected out in the first step , and the crop processing involves only the separation of the seed from the other crop parts such as chaff, straw, and glumes. This process does involve considerable labor and the number of hours invested in the harvesting process is more since it is a two step process, and often only worthwhile in cases of large land holdings. It is, however, noteworthy for



Figure 4-7. Type I Harvest Method of Type A Crops

archaeological interpretations.

In most cases, the crop plants are cut by selecting one to three plants at a time and then carried to the threshing floor where the heads are separated from the stalks before threshing (Figure 4-7). The harvested plants are stacked in a row in the field, and subsequently when a sizable bundle is formed they are taken to the threshing floor. In such a harvest, the weeds included in the threshing material are limited and comprise of only those that were harvested at a time with the selected one to three crop plants. This is significantly different from Type B crop harvesting.

Since it was not possible to observe a Type B crop which had weeds included in the harvested material (the 'Opportunistic' cultivation crop was sterile for any weeds), the research design was altered somewhat to accommodate this need. Pennisetum typhoides and Sorghum bicolor crops were harvested to simulate Type B crops while taking into account the processes that a Type A crop would be undergoing. So, Pennisetum typhoides and Sorghum bicolor were harvested by cutting at the base of the stalk, including all the weeds in the plot, as it would be if the crop were a Type B crop such as Panicum miliare. While this was done, the way Pennisetum typhoides and Sorghum bicolor would normally be harvested as a Type A crop was noted. This would have been by selecting only one to three plants at a time and thereby decreasing the number and types of weeds included in the harvested materials. These observations were made by noting which weeds were tall enough to be included in a Pennisetum typhoides and Sorghum bicolor harvest, since only the taller ones growing close to the bases of the stalks would get included in this harvest.

A distinctive characteristic of Pennisetum typhoides is that it seldom matures uniformly which in turn implies harvesting in stages, or by 'picking'. Rachie and Majmudar (1980) report two methods of harvest in unmechanized agriculture. First

involves the cutting of heads (as they mature) and placing them in the sun to dry, while the second involves the harvesting of the entire plants, removing the heads with a sickle or knife after a few days of drying. They report that this latter method is less frequent and is used when birds are less of a problem, soil is porous and dries up quickly during maturation (Rachie & Majmudar 1980). This could also be applicable to Sorghum bicolor.

Thus, it is important to note that Type A crops such as Pennisetum typhoides, Sorghum bicolor and Eleucine, can be harvested in three differnt ways. The first situation is the harvesting of only the heads, as discussed earlier, where the inflorescence heads bearing the grain are first harvested separately by cutting them from the stalk. This results in clean harvest material where there are no weeds or stalks, only the inflorescence heads bearing grain. The resulting threshing and consequent processing stages have only crop grain, rachii, florets, glumes and crop inflorescence heads without seeds as composition components. No weeds are present as byproduct components since they were not harvested initially with the harvest product. This type of harvest, though efficient in terms of cleaning involvement, is more labor intensive in terms of harvest time since the stalks are left in the field to be harvested again for fodder. This procedure is less common, and occurs only in select few cases where labor is not an issue. However, it cannot be ruled out for archaeological relevance. This is why it is important to isolate which inflorescence parts are distinguishing variables for different crop processing stages and pathways.

The second variation is when the inflorescence heads are harvested along with about 3/4 of the stalk. In this case some tall weed species are cut along with the stalk even when there is selection against the weeds by cutting of one to three crop plants at a time. This is the more common method, since it is only a one step process. Cattle

are left in the fields to feed on the stubble left behind. The inflorescence heads are often separated from the stalks on the threshing floor, and at this time some of the harvested weeds get included in the threshing material. Therefore, the subsequent processing stages have weeds to be processed out in addition to the other inflorescence parts. This is similar to the inflorescence parts processing if the harvesting was done the first way. The stalks are fed to cattle as fresh fodder.

The third variation of harvesting Pennisetum typhoides and Sorghum bicolor would be when heads, stalks and all weeds are cut together. In this instance, weeds of all heights, except the prostrate types, would be cut and included with the harvested material, as would be the case in the harvest of a Type B crops. The cutting would be at the base of the stalk, therefore, incorporating all the weeds which would not get included in the second type of harvest. This scenario is very rare ethnographically, but it is important not to dismiss it for archaeological applications. This is because it is possible that this type of harvesting could have occurred prehistorically when thicker stalk varieties of Pennisetum typhoides and Sorghum bicolor were not yet developed and it could be possible that with a thinner stalk this third type of harvest would have been the most feasible. Modern genetic manipulations have resulted in the selection and breeding for thicker stalks to provide more volume for fodder. It is therefore important to take into account all possible variations and study the resulting patterns for archaeological interpretation. It would then be possible to identify all these above mentioned variations of harvesting techniques archaeologically even though the techniques are quite homogeneous ethnographically. Ethnographically, the harvesting variation one and three are not as popular as variation two, but this might not be the case prehistorically, and the research design has taken into account this possibility.

During the study, it was imperative to note which one of these procedures will work for all three cases. It was decided that the third type of harvest method for

Pennisetum typhoides and Sorghum bicolor would be most representative of all three types, since the patterns of processing of the other two could automatically be deduced from studying the processing of the third type of harvest. Another way to view this is that the third type of harvesting is the superset within which the other two harvesting types are umbrelled. Therefore, it is possible to understand all three harvesting types by studying the third type. In addition, there will also be insights into Type B harvesting patterns, since the third type of harvesting of Pennisetum typhoides and Sorghum bicolor is similar to the harvesting of Type B crops.

It is important to note that this is not just ethnographic observation and study, but it is experimental ethnoarchaeology. This is because to learn certain types of information which are relevant prehistorically but not present ethnographically, a procedure was developed to recreate situations. This provides the means to understand the situation ethnographically and then model for prehistorical interpretations. We know the present is different from the past, and direct analogy is rarely applicable, and these kinds of ethno-experimental studies are necessary to avoid such errors common in direct analogy. This type of study is similar to growing plants and experimenting with them for domestication rates (Hillman and Davies 1992).

With the above in mind, the Pennisetum typhoides and Sorghum bicolor plots were harvested by cutting the crop at the base of the stalks and incorporating any weeds present. There were four steps in the harvest of each plot before the crop processing stages began. Step One included the harvest of all the non-prostrate weeds in the plot to ensure they get included, and then the harvest of the seed bearing inflorescence heads. Step Two entailed recording weights for the inflorescence heads, the weeds and the counting of the heads. Step Three was the harvesting of the rest of the plant and weighing it before it was used as fodder. The fourth and last step included the laying

out of the heads and weeds out on a cloth to dry, while the other plots were being harvested. The Pennisetum typhoides crop was harvested first and all the processing completed before the Sorghum bicolor crop and the Setaria tomentosa plots were harvested. The processing of these crops will be discussed together.

Crop Processing

In general (regardless of what crop is being processed) each crop processing stage produces two groups of assemblages: crop product and crop byproduct (or residue). The crop product (at each stage) is the selected assemblage for subsequent processes. The crop byproduct is the assemblage that has been processed out, and is that part of the harvest that is not included in the rest of the processing pathway. The compositions of these two assemblages are distinct from each other at each stage and at different stages.

The processing stages for the Sorghum bicolor and Pennisetum typhoides as Type A crops are different from the processing stages of Type B crops. The difference might not seem striking, but significant enough to make a statistically relevant variation. The Sorghum bicolor and Pennisetum typhoides crops are processed through roughly 11 stages after harvest and before they are ready for consumption. The following are the stages of processing for both Pennisetum typhoides and Sorghum bicolor (Type A crop processing).

1. Drying of the crop plants after harvesting

The harvested crop plants are well dried in the sun before the next processing stage. This is done so the seeds will be dislodged with ease from the heads. If the heads are wet this would not be possible. Also if the heads are wet, then there is a possibility of later fungal infection which could destroy the seed.

Preparation of the Threshing Floor

A hardened floor is prepared, usually at the edge of the fields, for threshing. Its function is to facilitate efficient threshing of the seed bearing plant parts, to reduce the amount of soil that would enter the threshing product and to reduce loss of seeds. Several steps are entailed in the preparation of the threshing floor which is a four day process. The selected area is first cleaned of all ground cover, approximately 5 meters in diameter. It is watered down well to settle the dust and left to dry for a day while periodically watering it. Two basket loads of dung are spread out and watered down modestly on the second day. Two bullocks are then walked over this slushy surface for 4 - 4.5 hours to harden it. After this the threshing floor is evened out by plastering by hand again smoothly with dung and water. It is then left to dry overnight, and on the third day it is plastered again, and ready for use the next day once it is well dried. It should be noted that when these areas are located in the fields they are subsequently ploughed and replanted, thereby obliterating them from the archaeological record.

2. Threshing with bullocks

Threshing is the process by which the seed bearing parts of the plant are separated from the non-seed bearing parts. The material to be threshed is laid out on the threshing floor, and then the bullocks held together by the farmer are led to tred on these materials in a systematic manner (Figure 4-8). This activity is predominantly done by men, while related activities such as sweeping up and other assistance is done by women. The dispersal of material from the heap is periodically swept into a pile to facilitate efficient threshing. This threshing process for each 25 meter square harvested plot took approximately 1.5 hours. The process results in a byproduct which is essentially made of inflorescence heads without seeds or with a minimal number of

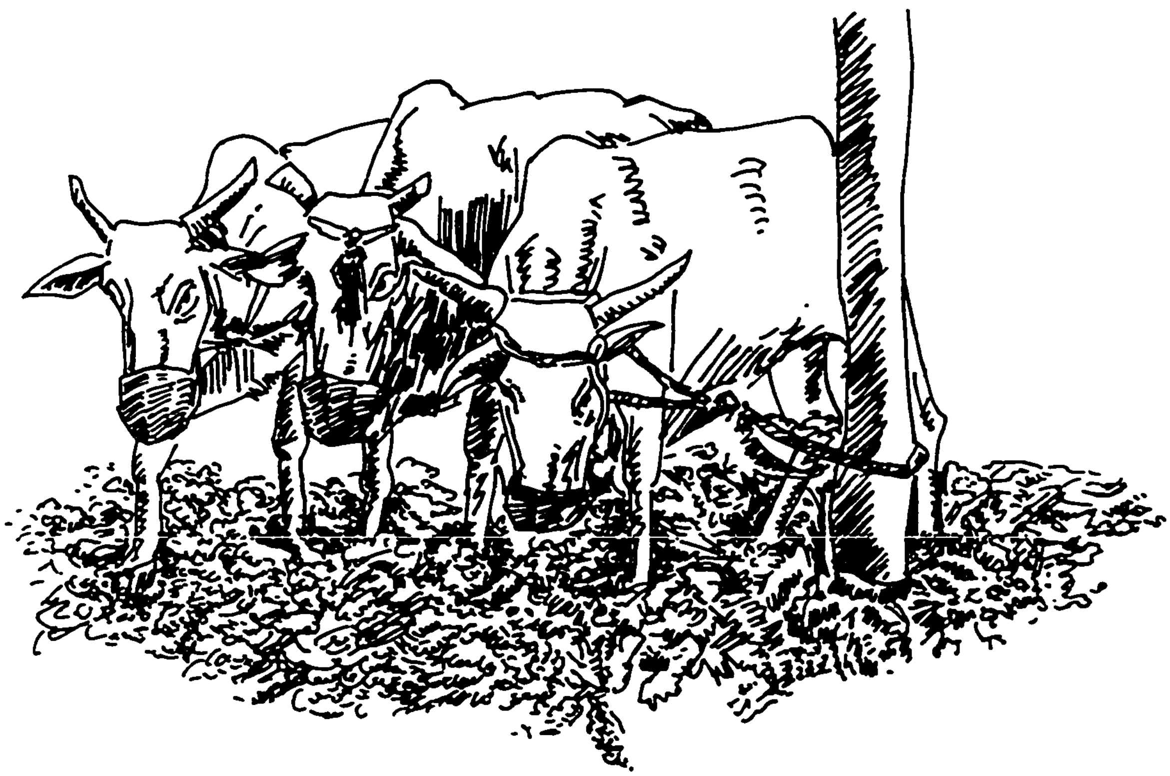


Figure 4-8. Threshing with Cattle

seeds, and small immature seeds. There are also weed seeds, and weed plants with and without seeds. This byproduct is fed to the cattle in the field. Occasionally it is taken home to be stored for later use. This later use is usually in about a month since Pennisetum typhoides and Sorghum bicolor stalks and chaff do not store well for long periods of time unless they are treated chemically. The threshing product is processed in the next stage.

3. Threshing with stick

After the threshing with the cattle is completed, there are often some inflorescence heads with seeds left unthreshed. Such heads are selected out from the pile and threshed on by beating with a stick. This selective threshing is more time consuming, and is an indicator of extensive farming. This activity is done by both men and women depending on availability.

4. Sorting

This activity is done after the threshing stage. It is done by hand, and involves the physical separation of desired versus undesirable plant material from the product. Sorting is done by men and women in preparation for the next stage. It is difficult to quantify this process, since most of it is subjective and dependent on the sorter, the crop and the time available for such an activity. Sorting after threshing can also be done with the use of a rake, wherein the straw and other vegetative parts are raked out leaving the smaller material for the next stage. The rakes were introduced into the area by the British, and the present day rakes look very much like the British Isles rakes. There is no distinct product or byproduct from the sorting process, since they are mixed into pre-existing groups of products and byproducts.

5. Winnowing (1)

This process involves the separation of grain from chaff, straw and other small light plant parts, and occurs on the threshing floor. Winnowing can be done through two methods: winnowing by wind and winnowing by shaking. For Type A crops such as Sorghum bicolor and Pennisetum typhoides winnowing by wind is done first followed by winnowing by shaking later.

By wind: The number of times one winnowing method is performed on a given crop product varies depending on the product quality and quantity. Winnowing by wind is a common method used in most parts of the world where traditional agriculture is practiced (Figure 4-9). It essentially uses gentle wind to separate out the light components, such as straw, chaff and spikelets, from the heavier grain. The threshing product is dropped gently from a height, the threshing product container is gently waved in the wind to maximize the operation. It is also maximized by standing on a height (in this case on a specific stand constructed with a triangular piece of wood with three holes into which fit in three legs). The heavier material such as the grain falls in a heap directly below the person winnowing, while the lighter material is blown aside where it is often collected to be used as cattle fodder. As winnowing by wind is done, the separation process is helped by another person who sweeps the tops of the falling heap, separating out the light smaller seed from the heavier bigger seed. This type of winnowing is a rough separation, and quite often the grain has to be winnowed again by shaking before any further processing can take place. Additionally, often after this stage there is a breakup of the process, and different parts of the products may be sent through different pathways of processing (See Figure 4-10). In general, the byproduct of this stage includes mostly chaff and light seed, both weeds and crops. The product

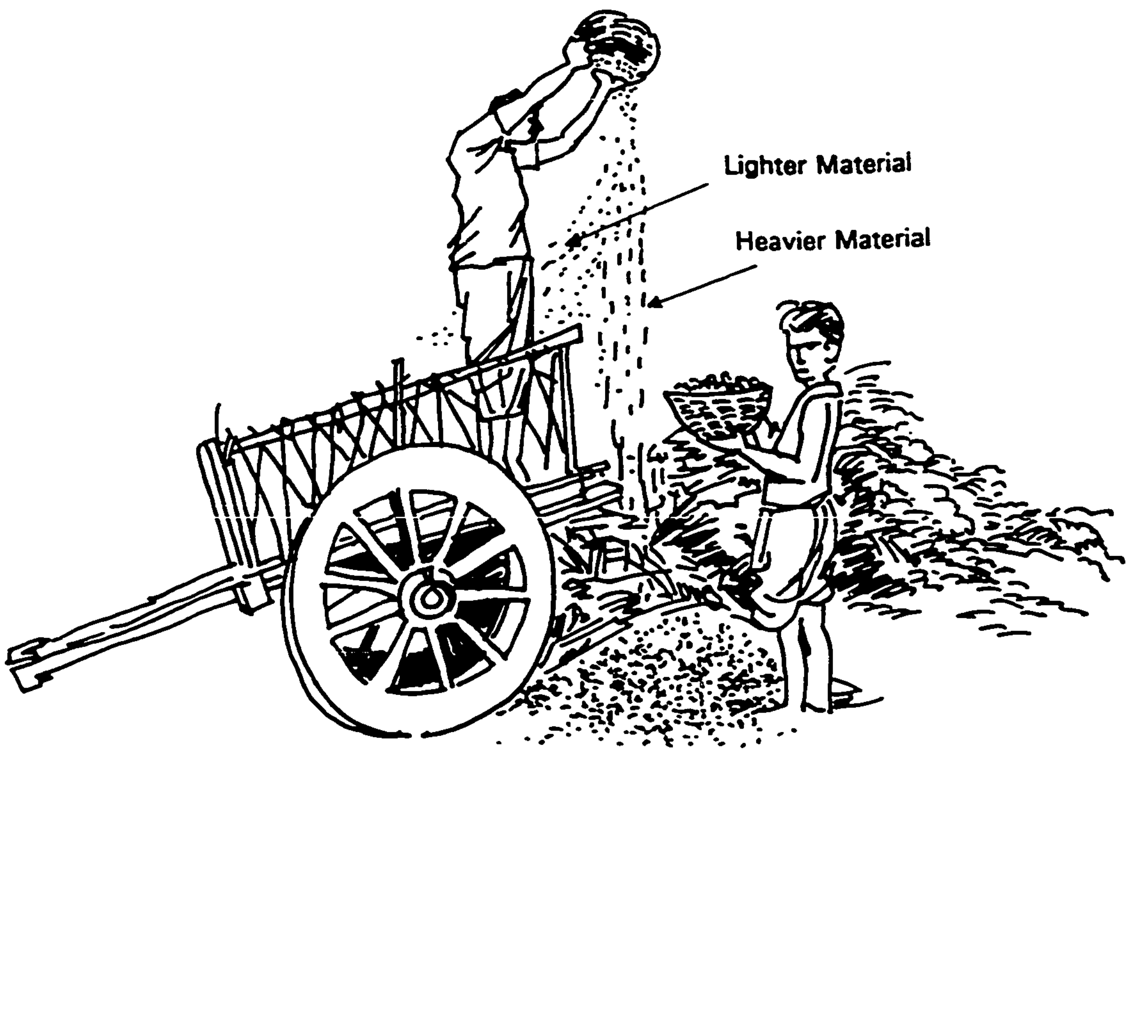


Figure 4-9. Winnowing by Wind

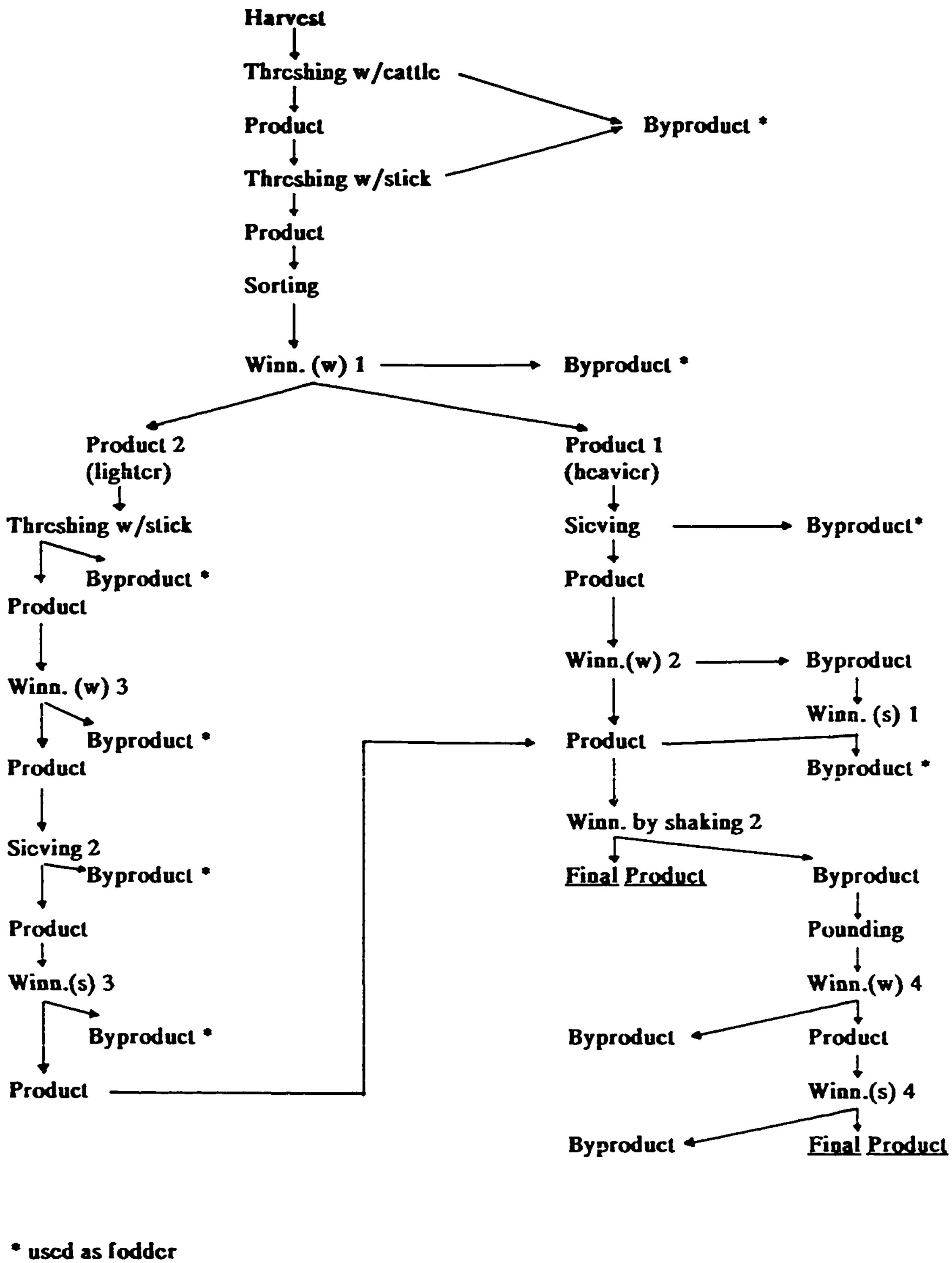


Figure 4-10. Pennisetum typhoides and Sorghum bicolor Crop Processing Pathways

has a higher percentage of grain (both weeds and crop grain), along with heavier plant parts associated with the seeds. The actual winnowing is most often done by men and the sweeping separation assistance is done by women.

6. Sieving

This processing stage is done mostly in the home bases by women, and quite often in the back or front yard area. In this stage, the Pennisetum typhoides and Sorghum bicolor seeds pass through the sieve, and the chaff and other larger materials which did not get blown off in the winnowing by wind process are left in the sieve.

The sieves are rectangular in size, and their sizes vary dependent on the quantity to be sieved. The diameter of the perforated holes is 7mm, and the sieve used in this instance was 1.03m long and 0.63m wide with a depth of 10cms. The perforated holes are in rough rows, and are about approximately 1cm apart. The sieves are now made of metal, but in many regions of the subcontinent bamboo or reed sieves are still in use. Such devices made with perishable materials would not be preserved archaeologically.

The byproduct from this stage is mostly straw, and heavier vegetative parts of the plant and the seed, while the product is composed of essentially crop-grain, weed seeds and smaller seed parts. This stage is an efficient method of decreasing the work load in the next winnowing by shaking stage, since the sieving removes the heavier straw which did not separate in winnowing by wind. This separation would be labor intensive in winnowing by shaking, but very efficient in sieving.

7. Winnowing by shaking (1)

This processing stage occurs in the homes, in the front or back yard areas by women. The process involves the rhythmic tossing, tapping and shaking of the crop product in a winnowing basket. The winnowing basket is deep, box-like and covered

with leather. This winnowing basket is markedly different from winnowing baskets of South India which are wedge shaped. This might affect the efficiency of the process, since the flaying of the basket contributes to the efficient separation during shaking and tapping. The cleaning of the grain is repeated a number of times, and the byproduct, which consists of small crop grains, weed seeds and crop seed parts, is given often immediately to cattle as fodder. The product still has some straw which can be separated only by winnowing with wind.

8. Winnowing by wind (2)

The third winnowing is similar to the previous winnowing by wind, but the only difference is that the material being processed is of different composition. This winnowing is gentler and slower to avoid excessive loss of grain. The byproduct is mostly straw bits, weed seeds and small light crop grain.

9. Winnowing by shaking (2)

This fourth winnowing is similar to the previous winnowing by shaking. It is done at the home base, and is often done at a later date, as a communal activity. The byproduct is fed as fodder to cattle and poultry dependent on the presence and number of these animals.

10. Pounding

This is done in select cases, when there are a significant number of small, crop grains enclosed in the spikelet florets. This is most often done after the second winnowing by shaking 2 (see 8), and if there are many small grains in the florets, then they are pounded and then processed.

11. Winnowing by shaking (3)

This stage is related to pounding, and occurs afterwards to separate the chaff dust from the grain. The byproduct is chaff dust and it is often small enough just to be swept off the area into the hearth or a trash dump.

12. Grinding

This is done using the grinding stone assemblage by women, and the objective is to make a flour of the grain for bread and porridge production. The grinding stones are laid out in a rotary grinding system in the homes. The rotary grinding system is placed in a raised wooden stand that catches the flour as it pours out the sides of the rotating grinding stones. There is no byproduct from this stage of processing. There is considerable amount of spillage of flour but it is insignificant for archaeological interpretation because it is very unlikely to survive. Such rotary grinding stones are not known from Harappan times, but flat, concave and saddle querns, and various shapes of pestles are quite common.

Use of Pennisetum typhoides and Sorghum bicolor

The Pennisetum typhoides crop is grown essentially for human food and the byproducts are used for fodder. The byproducts are not used for fuel usually since they do not burn well. When wheat byproducts are not available, then Pennisetum typhoides byproducts are used as temper for house and hearth construction. The stalks are more preferable as fodder than the chaff dust. The Pennisetum typhoides grain is rarely eaten as seed; it is most commonly eaten as a prepared flour, be it a fermented porridge or bread.

In some cases Sorghum bicolor crop is grown for two different purposes, and this is dependent on the season of growth. In the Babar Kot area it was noted that

Sorghum bicolor was grown as fodder in the summer with the use of monsoonal rains. It is also sown in February-March and then irrigated with well water for human consumption. The logic of this system is that when it is growing with monsoonal rains, then less care is taken and more care is given to the Pennisetum crop. This is done because Pennisetum typhoides has more market value in the region. When Sorghum bicolor is grown with the use of irrigation water in February-March then more care is given since more time, money and energy are invested. More wild fodder is also available for the animals at this time. The Sorghum bicolor crop grown for fodder is harvested green and fed to cattle immediately. This period of feeding also coincides with the lean period for wild fodder availability, since most of it is available in the winter months from November through March.

This is an interesting pattern of crop cultivation and is relevant to animal husbandry and seasonality. When there was limited well irrigation in the Babar Kot area, the seasonal river was tapped for irrigation by channels running into the fields which bordered the river. This was done in the recent memory of the farmers and during the previous generation.

OPPORTUNISTIC FLOOD PLAIN CULTIVATION OF Panicum miliare

(Type B crop cultivation)

Geographical Setting

The study of 'Opportunistic' cultivation was conducted in the northern part of the state of Andhra Pradesh in South India. Two main study loci were selected for the study and both are set on the banks of the River Pranitha, a tributary of the River Godavari (Figure 4-1), and are surrounded by fields of crops such as Sorghum bicolor, legumes such as Phaseolus, and occasionally maize. The selection of the two study

areas was based on economies of the dominant social groups, practice of 'Opportunistic' cultivation and potential for study. Since the area was and continues to be politically unstable, safety of personnel and timely completion of the study were my primary concerns. Therefore, some compromises related to selection of study areas were needed to accomplish the set goals.

The objective of the study of 'Opportunistic' cultivation was to understand the dynamics of this cultivation in terms of the labor, seasonality, crop husbandry and economic viability of this subsistence system. The two goals of the study were: to define the variables that distinguish the different crop processing stages and to understand 'Opportunistic' cultivation as a specific type of subsistence activity to model for Harappan systems.

Economy of the Study Area

The agricultural system in the area is predominantly dry farming, being dependent on the seasonal monsoonal rains, rather than irrigation. However, occasionally well irrigation is utilized, a luxury shared by a select few. The area was once densely forested but over the years it has been depleted and now only a thorn and shrub 'forest' with some heavy foliage remains. It is therefore conceivable that historically forest products could have contributed significantly to the subsistence base, despite being almost non-existent today.

The two study centers are quite distinct from each other, even though they lie opposite each other on either side of the river Pranitha. The village of Rapanpalli, lying to the north side of the river, is a very small nucleated village, while the town of Sironcha is larger and more dispersed. The distance from the village to the river is approximately two kms, while the town lies along the bank of the river (Figure 4-1). Agricultural fields surround the village of Rapanpalli, but do not surround the town of

Sironcha, since the river runs along one side. Because of this variation in the distance between home bases and fields, logistics vary considerably between the two communities.

Social organization in both the village and the town reflects the classical Hindu tradition, wherein the society is divided into four ritually stratified categories: Brahmana (Priests), Kshatriya (Warriors), Vaisya (Merchants) and Sudra (Laborers). Caste groups are normally endogamous and associated with a particular occupation. The two social groups whose farming practices are studied here, the Harijan and the Kapu, are outside the Hindu ritual hierarchical ideology and are commonly referred to as the 'untouchables'. With modernization, however, there has been a general decrease in the importance of the varna/caste system. Economic differences are becoming more determinant of one's role and status in society rather than ritual differences. In both Rapanpalli and Sironcha, even though the ritual hierarchy is honored, political status and economic class are increasingly more relevant in the social organization. Landowners who are economically independent are quite often the ones who exercise decision making within the community.

The subsistence economy is predominantly farming and fishing, with the latter being an occupation restricted to a particular social group of people from both the town and the village. For this study the location of seasonal fishing is important because it occurs in the same locales as the 'Opportunistic' cultivation, and is an excellent example of several subsistence activities occurring in the same niche. Fishing in this area is affected significantly by the season, and even though fishing could be done throughout the year, there are parts of the year when it is not viable, such as in the midst of the monsoonal rains between June and September. Typically, the fishermen construct temporary huts on the broader western floodplain of the river Pranitha every

year as soon as the flood water recedes after the monsoonal flooding. The entire family moves into the huts in October and remain there until just before the monsoons begin in June, however the home base is visited occasionally to ensure its safety. The temporary huts on the floodplain are one room structures built of bamboo and reeds. There usually is an outer veranda area where fish are processed for the market: this includes the drying of small fish for both household consumption and distant markets. The fishing is done with nylon nets, since traditional fishing nets are no longer in use. Very often bank loans are taken to buy these expensive nylon nets, and they are often the main investment for the family. Daily catches usually include freshwater fish and shrimp. They are taken to the town market daily and whenever possible taken to nearby towns by bus. Since the duration of their stay on the flood plains is quite long, a significant amount of ashy refuse builds up near the temporary structures of these fisher people. Circular domestic refuge areas are distinctly visible. Non-perishable materials such as pottery, metal tools, fish hooks, net weights, along with domestic activity related discard such as hearth cleanings, charcoal and fish bones are found in abundance. However, these remnants of the seasonal camps are washed away with the yearly flooding of the river, and would not be visible archaeologically. This is an important observation to note because such groups and their habitation loci could almost never be found archaeologically, but they are significant contributors to the subsistence economy of the society in ethnographic present, and there is no reason to assume otherwise prehistorically.

Farming is the other primary subsistence activity in the region, and it mainly consists of monsoonal rain-dependent dry farming. There are situations however, when a second crop is planted in December utilizing either the remaining ground moisture or well irrigation. Crops of Sorghum bicolor, various legumes and maize are cultivated on the terraces and the higher banks of the rivers. House gardens are very common,

usually consisting of a variety of vegetables, legumes and maize, all for household consumption. The household crops are intercropped (the cultivation of more than one crop in a given plot of land) and often the combinations vary according to season and need. These crops rarely enter the market system, and are often cultivated by irrigation from the neighborhood water supply which is most often a well. In the larger land holdings, traditional methods of farming are most prevalent; for example, most land tilling is done with bullocks and a wooden plow. The wealthier landowners use tractors. As with any farming system, there is seasonality in activities, with the sowing and harvesting seasons being highly time consuming, particularly due to the traditional methods of farming and the absence of mechanism. Land tenure as relevant to this paper is unequal, with the lower castes and the 'untouchables' having little or poor land. The Harijan and the Kapu, owners of poor land, are the groups who engage in a specific type of cultivation termed 'Opportunistic' cultivation (Reddy 1991).

Opportunistic Cultivation

'Opportunistic' cultivation is practiced in the clayey deposits of the active river floodplain. The farming community involved in this specialized cultivation are essentially the economically poorer sections of the each community: the Harijan and the Kapu. They cultivate these deposits as a communal activity with the profit and the labor investment being shared equally. It is practiced to supplement the subsistence, and very often it contributes significantly to the subsistence base, given the low investment of labor in comparison to the cultivation on the banks where land preparation and weeding are heavy time and labor investments.

The crop cultivated in these deposits is <u>Panicum</u> <u>miliare</u>, because it seems to be the only crop which can grow in such heavy clay soils. <u>Sorghum</u> <u>bicolor</u>, the other

millet grown on the upper banks, does not grow in this thick clay deposit, nor is there any other locally known crop that will grow in such deposits except Panicum miliare. Typically, Sorghum bicolor can only be grown in the sandy clay deposits near the edge of the floodplain, while Panicum miliare is grown in the thick clay closest to the water. Panicum miliare cultivation is one eighth the effort of Sorghum bicolor cultivation in terms of the time invested in its cultivation, but its yield in seed is one quarter the yield of Sorghum bicolor. The cultivation is primarily done as an opportunistic activity on the clayey flood deposits on the flood plain (Figure 4-1). This is public land and the only initial investment for this cultivation is the sowing time and the cost of the starting seed. According to the older local informants, there is a long history of such 'Opportunistic' cultivation in the study area. How long it has been an activity specific to the lower castes and the poor landowners is not known. In addition, there is at least one example from the Gangetic floodplains in North India, where Panicum miliare cultivation is done also as an opportunistic activity (personal communication with a farmer). Such cultivation is significant as it provides insight into a traditional agricultural flood plain activity, which could have implications for understanding agricultural utilization of flood plains in other areas of the world.

The monsoonal flooding of the river occurs during and after monsoonal rains, between July through October. 'Opportunistic' cultivation exploits the summer monsoon rain flooding of the rivers. The river swells and floods the adjacent plain (in a matter of days), and the floodwater often remains for two to three months. When the water recedes (often a slow, gradual process over a month or so), the clay is left behind on the flood plain as a thick deposit which gradually thins from the river to the edge of the bank. That is the thickest part of the clay deposit is closest to the river, and the thinnest deposit is furtherest from the river. The thickness of the clay deposits vary considerably from year to year. The deposits stretch along the river course, and their

presence is determined by the slope of the floodplain, velocity of the river, amount of flooding every year and the rate of water recession after the monsoons. At the time of this study, the thickness of the inundation deposit was 1.1 -1.2 m closest to the river, and it extended a width of 28 meters. The clay is quite well sorted, with almost no sand or silt composition. During the sowing of the Panicum miliare crop, the clay is quite viscous, but as it dries up it breaks into well demarcated blocks. The breadth of the clay deposit is unpredictable and is often dependent on the flooding sequences and the volume of water flooded by the river Pranitha. One of the most important characteristics of these clay deposits is that they are barren of any type of weed seeds, thereby making the deposit in which Panicum miliare is sown essentially a sterile clay bed. This is an important feature because weed seeds growing in crop fields very often are included into the crop harvest, and have to be processed out through various processing activities. When and how these weeds get selected out is dependent on their own characteristics and also the processing stage. Weeds have been used (Hillman 1984; Jones 1987) as indicators for the different stages of processing. Therefore their absence has obvious significance in the study of crop processing of Panicum miliare.

Botany of Panicum miliare

It is imperative to briefly discuss the botany of the crop Panicum miliare, in order to discuss the compositions of the different product and byproducts of different stages of processing. 'Crops' are included within a broad definition of plants cultivated by man for a variety of uses. Not all crops are domesticated. Cultivation means to perform a range of activities related to the caring of a plant and manipulation of the plant for the ultimate use by man. Panicum miliare genus has about five hundred species, but the most important species economically are Panicum miliaceum and

Panicum miliare. Both these species grow well in hot climates and poor soil. They grow rapidly and mature more quickly than any other cereal.

Panicum miliare Lamk. is a hardy plant and capable of producing a crop on the poorest of land and able to withstand conditions of drought and waterlogging. This is the main reason why it is cultivated on the floodplains in the form of 'Opportunistic' cultivation, because in this form of cultivation water logging conditions are typical after sowing. Panicum miliare is also called Panicum sumatrence Roth ex Roem. & Schult, and it is grown extensively in India but rarely elsewhere. It occurs wild in northern India and southeastern Asia (Purseglove 1972). The husked grain is cooked in the same way as rice and it can also be made into flour. The soft straw is palatable to cattle and the green plant has potential for use as a quick growing fodder. The crop needs little attention and can give a crop, albeit small, even in famine years. It matures in 2.5 to 5 months. It is an annual tufted grass with rather slender culms, 30-90 cms high, soft leaves up to 60 x 2.5 cm, oblong panicle 14-40 cm long, erect hairy branches, spikelets 3-4.5 mm long, glabrous, flattened, caryopsis are glabrous, striated brown (Figure 4-11). The plant tillers profusely, and attains a height of about 2-4 feet depending on the variety. The panicles are about a foot in length, with drooping filiform branches. It is a dryland crop, highly drought resistant, and matures quickly, generally in approximately 80 days. Panicum miliare is known as a crop that grows well in poor soils and is often grown as a 'famine' food (Aiyer 1982).

Problem Orientation

The study of crop processing stages helps define and isolate variables, such as plant parts, weeds and tools, which can distinguish the different stages products and byproducts as distinct assemblages. These can be used for archaeological interpretations, and the definitions of prehistoric archaeobotanical remains. The

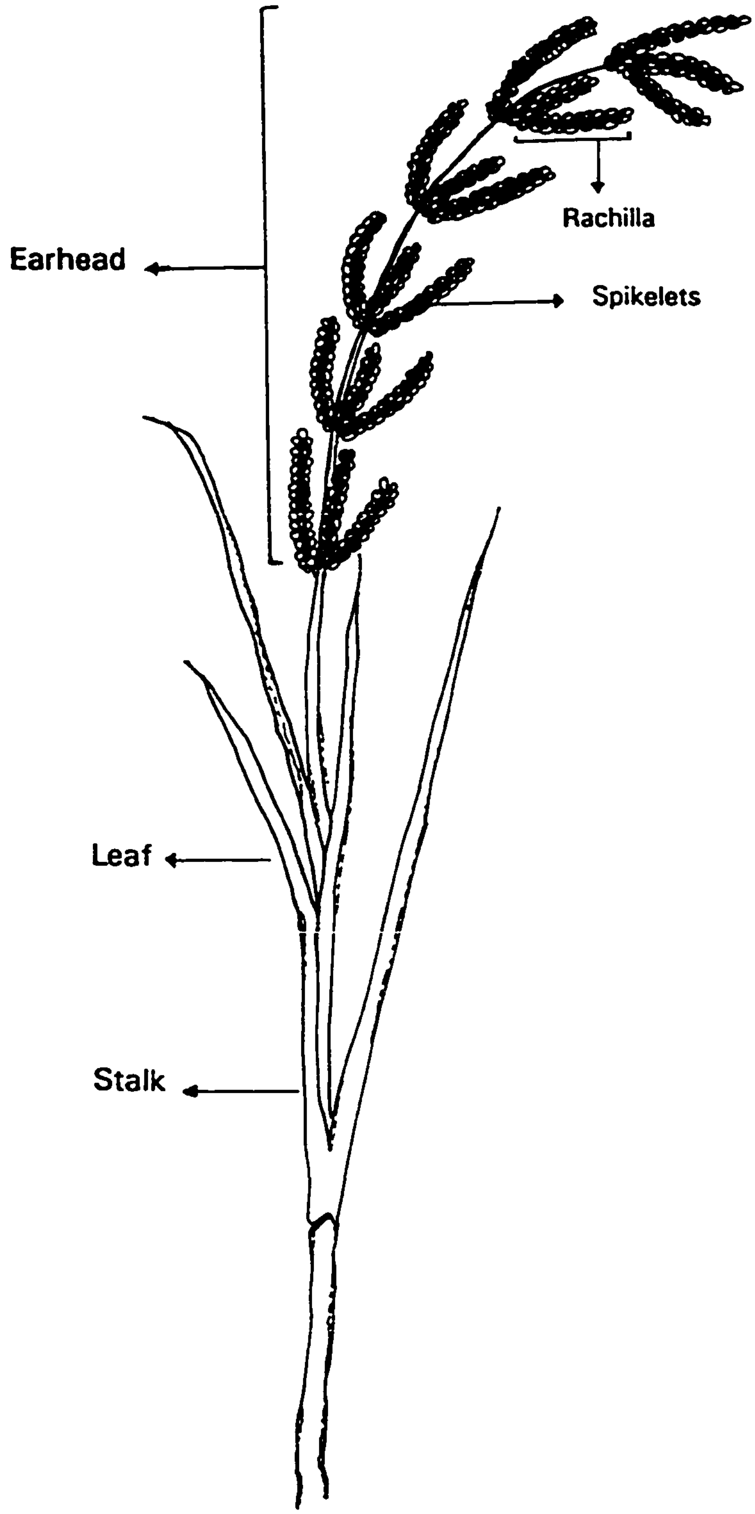


Figure 4-11. *Panicum miliare* Plant

'Opportunistic' cultivation system provides a specific system for study otherwise not available. It will prove worthwhile to study the processing patterns and compare to the other systems of cultivation, both in South Asia and in other parts of the world. Riverine floodplain cultivation is a very common subsistence activity, and the 'Opportunistic' cultivation provides the most likely scenario of subsistence activities on the dynamic river floodplains.

Field Methodology

Since the main objective of the study was to examine the crop processing activities for archaeological applications, the crop fields were treated as archaeological sites, and sampling was done within each discrete crop field 'site'. Two stretches of Panicum miliare along each side of the river were studied in order to understand the dynamics of this form of cultivation. Two questions were of particular interest: (1) is there any variation within and between the crop fields on each side? (2) does the variability in the width of the floodplain on either side of the river create any observable differences in their fields?

To answer these queries, a thorough reconnaissance was done to identify visual differences within each field and between fields on both banks. The crop fields on both banks were surveyed, noting any particularities such as absence or presence of weeds, density of crop, maturity of crop and other physical features that would be useful parameters of measure. After careful study, it was evident that weeds were present only on the Sironcha bank (Figure 4-12). This was due to the proximity of the field to the terrace bank, which contributed weeds seeds to the field through erosion. All the weeds were low lying, ground cover varieties and seemed to be at an earlier stage of growth than the Panicum miliare crop. On the Rapanpalli bank, however, there were no weeds in the fields (Figure 4-13).

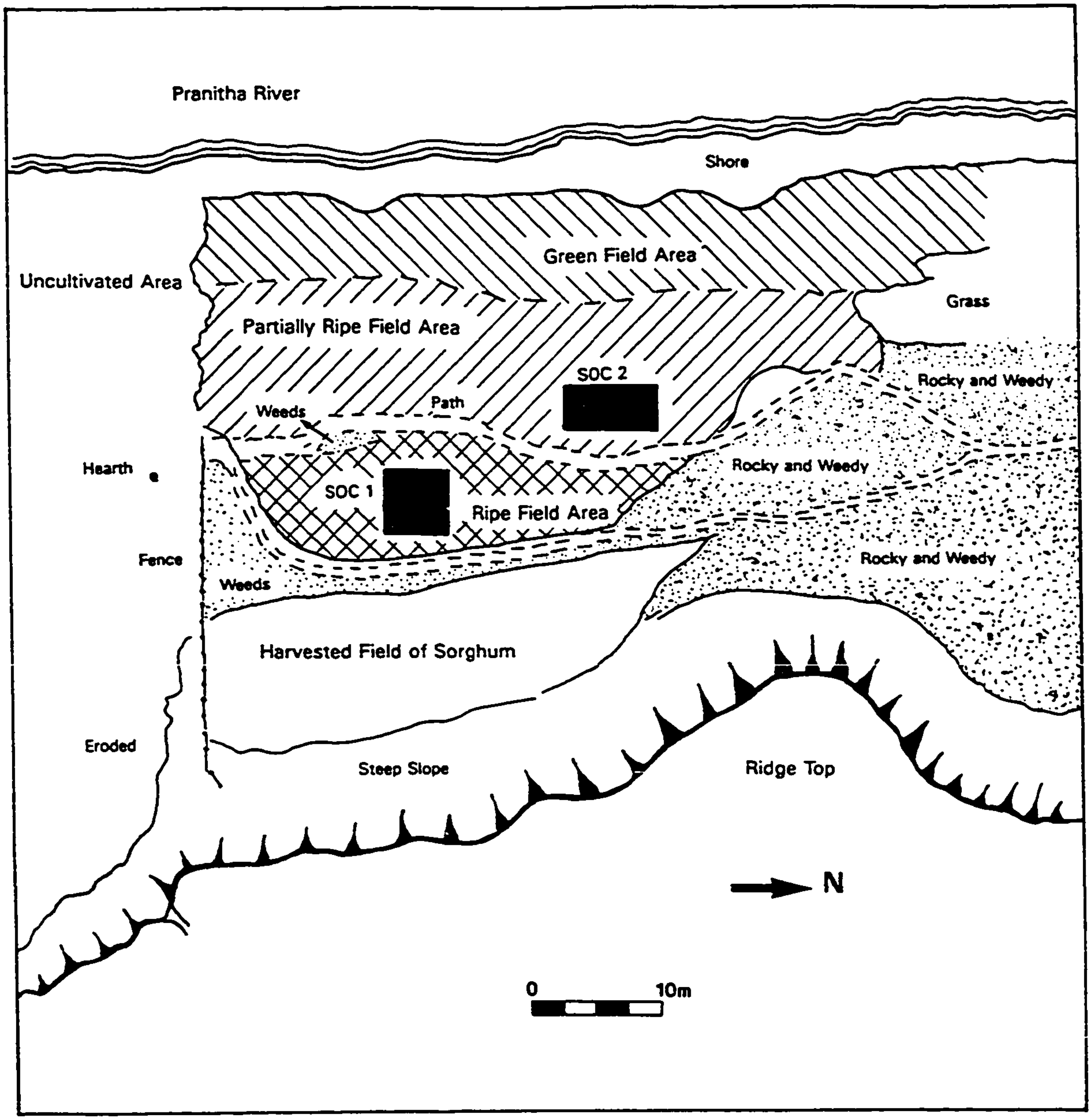


Figure 4-12. Sironcha 'Opportunistic' Cultivation Study Plots (SOC)

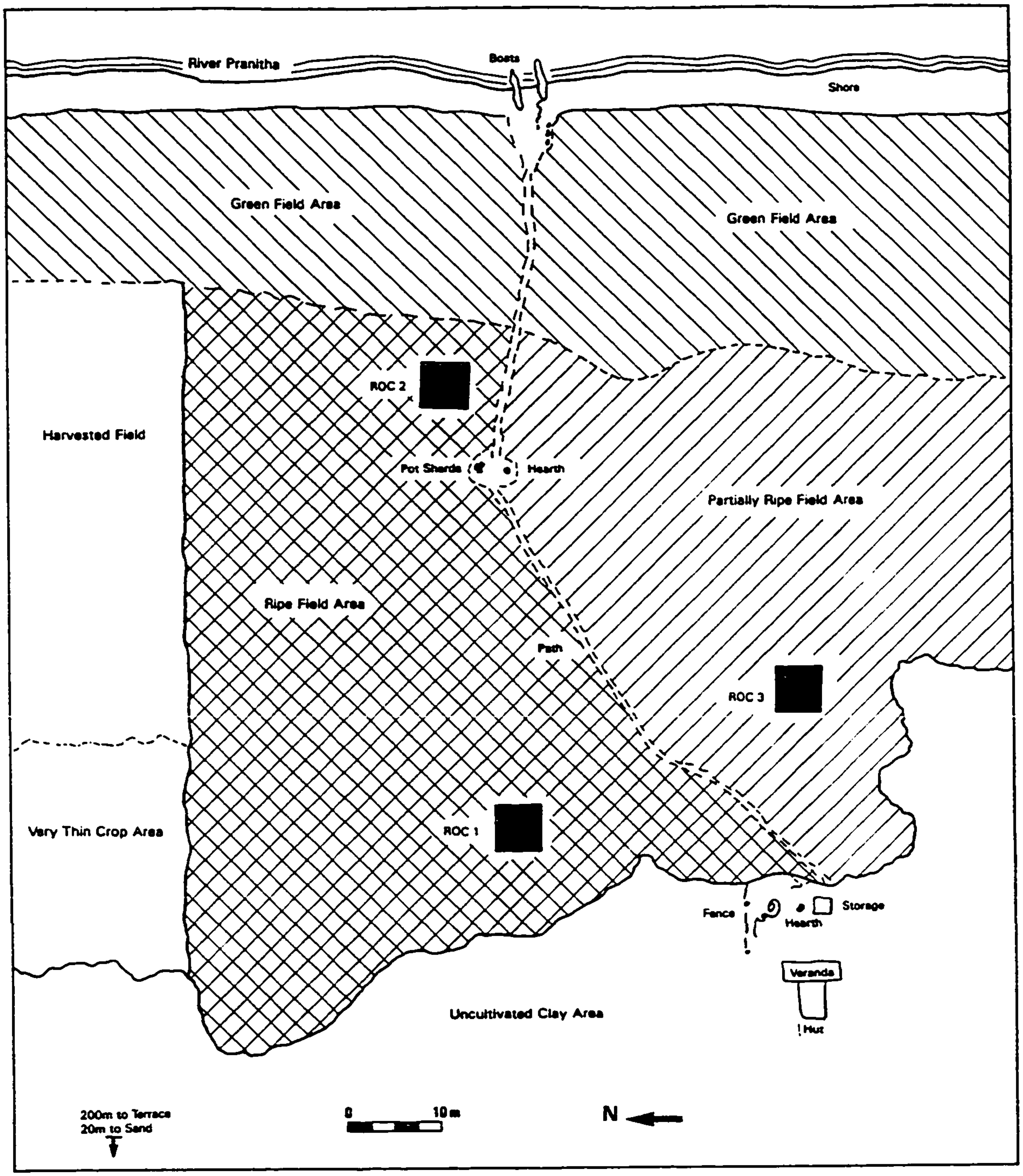


Figure 4-13. Rappanpalli 'Opportunistic' Cultivation Study Plots (ROC)

The fields on both banks showed no variability in the Panicum miliare crop distribution but considerable variability in the maturation of the crop. On both the banks, the plants closest to the water were still immature, while those furthest away were ready for harvest. Therefore study units on both the banks were selected based on criteria such as: least trampled, most isolated, closest to bank or mature/dried.

A total of five study units each of 25 sq. meters were laid out in the two fields, and then the ratio of crop plants to weeds was calculated by counting the plants. This ratio is used to determine significant variables regarding relationships between yield, proximity to water, byproduct compositions and important differences of the compositions of the plots with known quantifiable differences. To determine the ratio, the parent plant and corresponding tillers were all counted as one, since they all grew out of a single parent. First, as an experiment to determine an efficient method of counting, the plants were counted before harvest and then after harvest the stubs were counted. Since there was no significant difference, the latter method was employed as it is logistically more efficient. The five study plots were selected where crops were mature for harvest: closest to river, furthest away from river and midway (which was also on a path). Selection of these 5 X 5 m study plots was done based on three criteria: least trampled, most isolated, and well dried and matured. Each 25 sq meter plot was treated as a separate unit and studied in a similar manner.

Each stage of processing after harvesting was recorded, with specific emphasis on the process description, the quantities of crop product and crop byproduct at the end, the techniques used, and the uses of the byproduct and product when relevant. The weights of the products and byproducts were recorded, and specific quantities of the products and byproducts were taken for later composition analysis. Great effort was made to take homogeneous samples from the product and byproduct piles from each stage of processing. The piles of crop being processed were mixed from the bottom

and the top and then a sample was taken for analysis. This limits any error of bias due to smaller seeds and plant parts trickling to the bottom of the pile, and the larger straw like material being on the top of the pile. This is a more critical issue in the earlier stages of processing than the latter stages when the seeds are more uniformly weighted.

Sowing

In 'Opportunistic' cultivation Panicum miliare is sown in the clay deposits around October when the flood water has receded, but the clay is still very moist and viscous. If the clay is dry, the seeds will not germinate. The clay deposit has to be a minimum of 0.6m (60 cms) thick for Panicum miliare cultivation. Sowing is done by hand broadcasting; a pot is attached to the sower's belly (for buoyancy and for holding the grain) and seeds are broadcast as the sower wades through the clayey slush deposits. The sowing is done in strips parallel to the river, as the water recedes over a period of time. Because of the staggered sowing, portions of the field mature at different periods, with the strips furthermost away from the water/river first to be sown and first to mature. This is an optimal strategy for labor investment, since only small portions of the field are ready for harvesting at one time. This planting strategy is also employed in dry farming fields on the banks, plains and valleys with some patches sown before others to facilitate timely harvesting and optimization of labor. Once sown, the crop of Panicum miliare is not given any other attention in terms of weeding and tending. This is important because it signifies the extensive nature of the practice, with minimal effort and energy invested into cultivation. In the following discussion the different stages of crop processing are presented, as they are relevant to the processing of Panicum miliare in 'Opportunistic' cultivation in South India.

Harvesting

Harvesting is the reaping and gathering of grain or other products from the plant. This can occur in two ways: uprooting of the plant (where actually there is no separation of the component such as a panicle from the rest of the plant), and the cutting of the grain bearing part from the vegetative parts. Uprooting is less common in India as it is often more labor intensive in the subsequent stages of crop processing. It is more common when the crop concerned is being grown for fodder, and the subsequent stages are irrelevant. The second method of harvesting, cutting, is the most common method.

The Panicum miliare crop is harvested in a Type II method, by cutting a bunch of plants at one time with an iron sickle. Bending down at the waist, a number of plants are gathered in the left hand by the harvester, and then cut with a sickle held in the right hand (in the case of right handed individuals) (Figure 4-2). The stubble left behind on the ground is about 12 cms high. The harvested plants are heaped in a pile and after the harvesting is completed, they are then tied into manageable bundles using a stem. Harvesting is done by both males and females.

In the study units on the Sironcha bank, even though weeds were present in the fields, they did not become incorporated into the processing products or byproducts, because of the type of weeds. These prostrate weeds were below the level of the sickle cut for the Panicum miliare plants. In cultivation of Panicum miliare on the plains, this type of harvesting would result in the inclusion of weeds into the harvested bundles which would not be selected out until later processing stages. This particular 'Opportunistic' cultivation by the inherent nature of the sterile flood deposits does not present that situation.

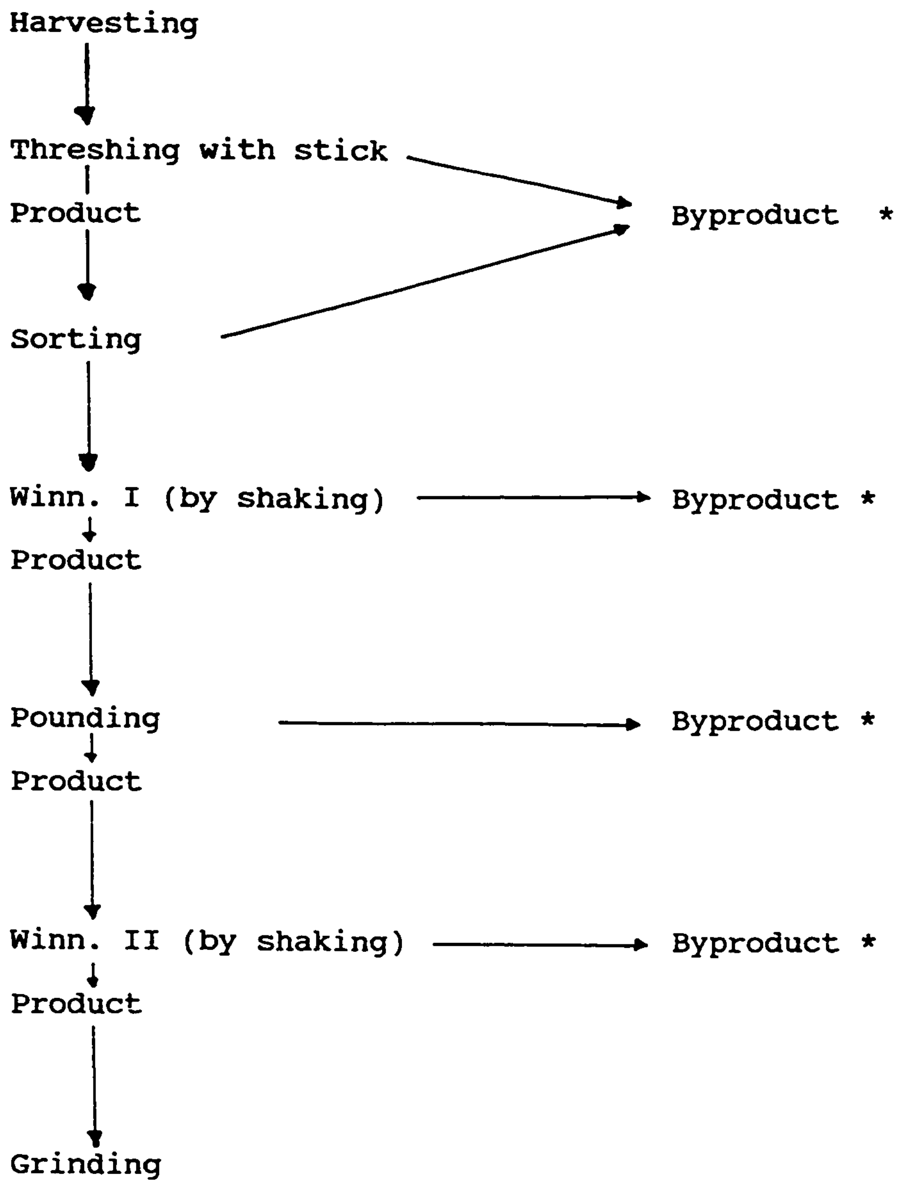
This study has also provided new insights into harvest timing and its direct influence on the yield. The preference for Panicum miliare is to harvest it slightly green

(as it occurred in the study units on the Sironcha bank), while for a crop like Sorghum bicolor a more ripe state provides a higher yield. When the Panicum miliare crop is well mature and dry, there is a significant loss of grain during the harvest because of the brittle nature of the panicle. The seeds from the panicle head in a green Sorghum bicolor crop, however will not dislodge as effectively as when it is dry, and there will be a greater loss of seeds in the processing. This difference could be an indication of the degree of domestication of each of the crops: Panicum miliare being less domesticated as defined by the more brittle nature of the plant's panicles.

The harvested bundles are often laid out to dry in the sun, but this is again dependent on the state of the crop. If it is well dried it need not be dried out before threshing, but if it is partly wet then it is well dried in the sun before threshing.

Crop Processing

Crop processing techniques and the patterning of crop products and crop byproducts after each stage were recorded within each of the five study units. The Panicum miliare crop has an average of six main processing steps leading to consumption (Figure 4-14). These include threshing, sorting, winnowing I (by wind and/or by shaking), pounding, winnowing II (by shaking), and grinding. It was noted in this study, that there are specific tasks for men and women, though there is occasional overlap and sharing of activities. For example, sowing is done predominantly by men, while tending the fields (keeping the animals away) is shared by both. Since the fields are joint cultivation holdings by communities of the Harijan and the Kapu, the activities are not restricted to any single family. Instead, a number of individuals from different families partake in the sowing, tending and crop processing.



Final Product to be used as human food

* used as fodder

Figure 4-14. Panicum miliare Crop Processing Stages

1. Threshing

Threshing releases the seed along with its attached appendages from the plant. Threshing is done in one of three different ways: beating with a stick, rubbing and stamping with feet, and/or trampling by cattle. Threshing by beating with a stick and the use of cattle is done predominantly by men, while threshing with feet is most often done by women. Threshing by stick or feet is determined by the maturity level of the crop. If very dry, then stick harvesting is done, but if the crop is still green then feet threshing is done. The preferred method of harvesting Panicum miliare is while it is still green or else much of the grain is lost during harvest. In both methods, the crop plants are laid in a heap on the threshing floor.

The Panicum miliare crop in this study, was threshed in two different ways: beating with a stick and by rubbing and stamping with the feet. The crop from the Rapanpalli bank, which was drier, was threshed by beating with a stick, while the crop on the Sironcha bank was greener and less dry, so it was rubbed and stamped on by feet. The chosen methods of threshing optimize the amount of grain retrieved, the time invested for the amount of crop and, most importantly, the type of crop (in this case Panicum miliare). The seeds of Panicum miliare are very small, and using cattle for threshing would lead to considerable processing loss.

Threshing in 'Opportunistic' cultivation is typically done in the fields away from the home base. The threshing floor is often prepared by cleaning the area first, and then plastering it with cow dung. This is often done few days in advance in order to give it time to dry. The reason a floor is plastered is so that there is minimal loss of grain into the sediment, making it easy to gather up the threshing products through hand sorting. In the subsequent analysis of the threshing products for the two different threshing samples, it is noted that the product of threshing with a stick has more straw and panicles in it, in comparison to the product from threshing with rubbing of the feet.

This is significant because it affects the Winnowing-I process, in terms of amount of byproduct separated out and the time invested in the activity. More importantly, there was also a significant difference in the amount of grain retrieved through the two different threshings, with a greater loss of grain when threshing with a stick.

2. Sorting

Sorting, the separation of crop product from its byproduct, is done essentially by hand and is equivalent to the raking stages in European crop processing. The byproducts here are the Panicum miliare plants which have had the grain removed. They are gathered up from the top of the threshing heap, and piled separately. They are then used as cattle fodder, while the threshing product, which includes the seed, is processed further. Both men and women help in the sorting.

3. Winnowing I

After threshing, the crop is winnowed to separate the grain from chaff, straw and spikelets. Winnowing can be done through two methods: by wind or by shaking in a winnowing basket. The method used for Panicum miliare is that of winnowing by shaking with the use of a basket. This method is specifically chosen because of the small size of the crop seeds. Winnowing by shaking is more appropriate for these small sized seeds because it can be controlled effectively (as compared to winnowing by wind) to avoid excessive loss of the crop grains. This activity is done at the threshing floor in most instances. However, if there are other pressing activities, the threshing product is then taken to the houses and processed there. The straw, chaff and spikelets that are separated from the grain through winnowing are then added to the cattle fodder. The winnowing process stage involves a series of winnowing (regardless of

method of winnowing). The series of winnowings cannot be regarded as separate winnowings because they are done sequentially (without them being considered as separate stages). The series of winnowings continue till the product is cleaned of all the non-desirable components.

Winnowing by shaking is done using a winnowing basket which is woven and rectangular wedge-shaped (Figure 4-15). It is thin and smooth, and often plastered with dung and turmeric (a disinfectant spice) to ensure a smooth surface. The grain is placed in it, and then by the rhythmic tossing of the grain, followed by the shaking of the winnowing basket, it is separated from contaminants such as straw, chaff, spikelets or weeds. The cleaning of grain is repeated many times until there are no contaminants. This is a time-consuming and labor-intensive process, but there is very little loss of grain (unlike winnowing by wind) and is very effective separating grain from chaff. This activity is done predominantly by women. If the grain is not used immediately, it is stored or taken to the market after this stage of processing.

4. Pounding

After the grain has been cleaned, it is pounded to separate the seeds from the husks (Figure 4-16). The grain is placed in the depression of a grinding stone and then pounded with a thick heavy wooden staff. Through repeated pounding, the seeds are separated from the husks. If the grain is partially ripe when harvested, quite often it is roasted over a fire before pounding to facilitate the efficient separation of the husks. If the grain is well ripened at the time of harvest, it is dried in the sun before pounding. This distinction is important for archaeological inferences since it has the highest probability of accidental burning and preservation in archaeological record.

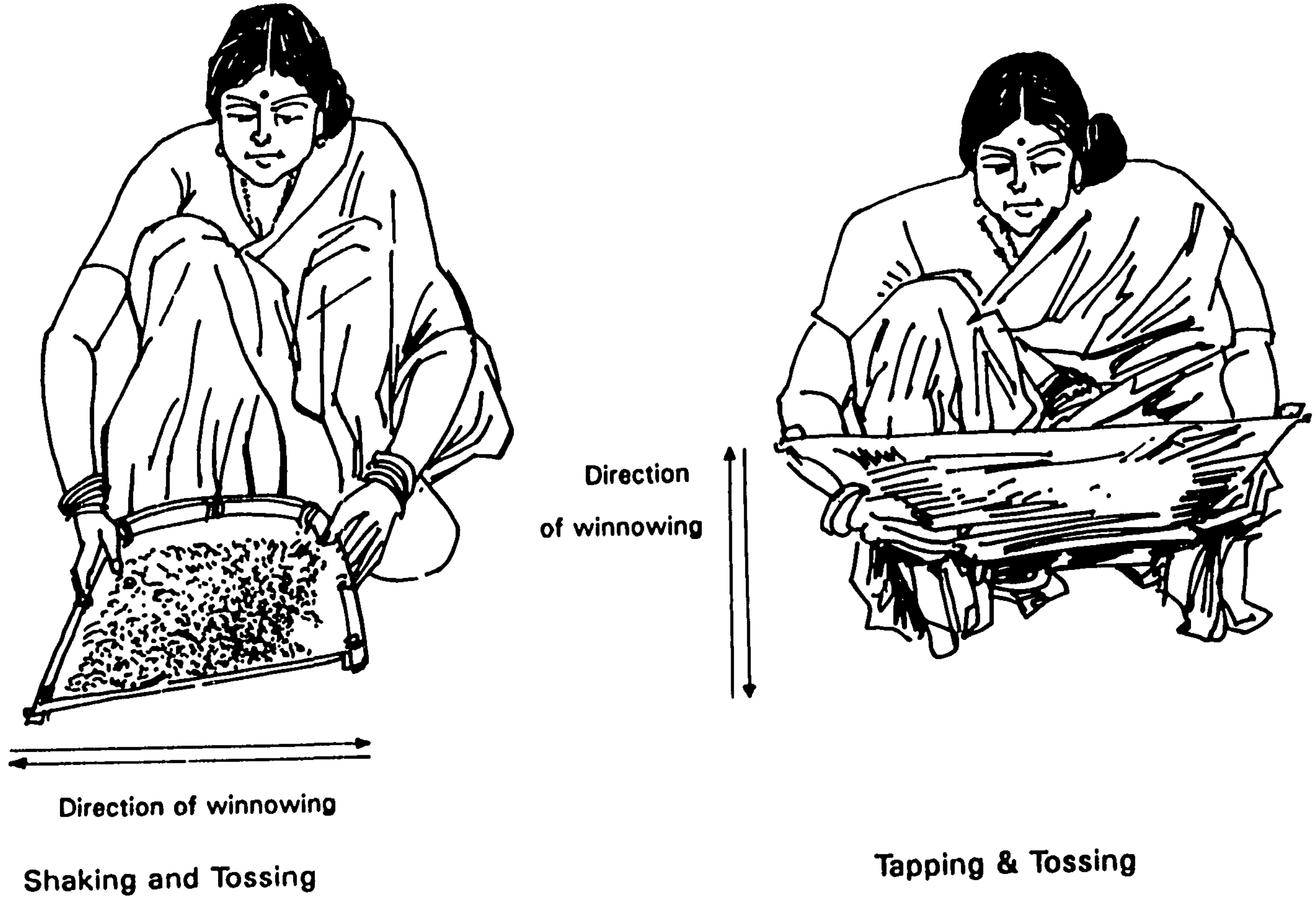


Figure 4-15. Winnowing by Shaking

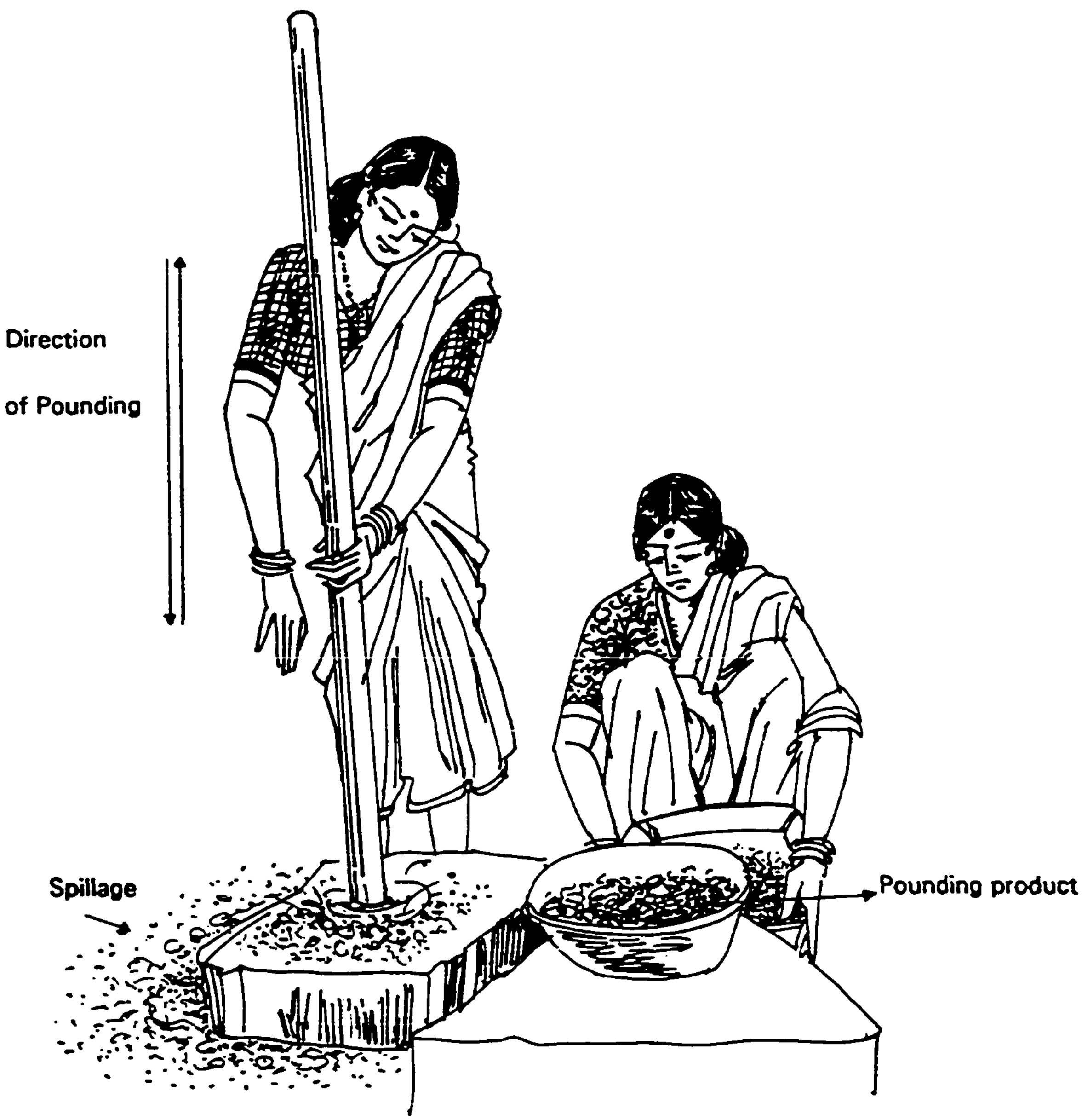


Figure 4-16. Pounding

5. Winnowing II by shaking

Once the seeds are freed from the husks through pounding, winnowing by shaking is done to separate out the seeds. The fine chaff dust that is separated is an attractive cattle fodder. Often the seeds are cooked similar to rice after this stage of processing.

6. Grinding

In some instances, the seeds are further pounded into a flour and then consumed as a porridge-meal. This is done through a process similar to pounding. One of the differences between the two processes is that there are no byproducts from grinding, for even though there is spillage, it is not significant in terms of quantity and archaeological preservation. Panicum miliare flour can also be made using a rotary grinding method. This entails two circular stone slabs set one upon the other. The grain is dropped through a hole in the center of the upper stone and while the upper stone is rotated by hand, and ground flour then flows out the sides.

Use of Panicum miliare byproducts

All the Panicum miliare byproducts from threshing, winnowing I and winnowing II (including straw, panicles, chaff and chaff dust) are used as fodder. This material is not storable for long periods, and the forage has its highest nutritive value when fed fresh soon after the crop processing. Panicum miliare byproducts are never used as fuel. The comparative low nutritive value of Panicum miliare grain and its non-storability, makes it a less attractive crop to grow primarily for human consumption. Instead it is ideal as a short term human food supplement when grown in an opportunistic manner.

Discussion

'Opportunistic' cultivation presented here stands as an important form of traditional agriculture. It has historical longevity in the area, particularity in terms of the clay deposit, type of crop cultivated, nature of cultivation and the absence of weeds in the fields. All these contribute to making it an important case for the further understanding of floodplain agricultural systems (past and present), communal labor and investment. Specifically, new insights have been gained regarding existent floodplain agricultural systems. The communities involved in this cultivation belong to the lower castes who also happen to own the poor non-irrigated land. Only this sector of the rural society partakes in 'Opportunistic' cultivation; and their participation in this cultivation is uncertain if their land holdings were irrigated and high yields of Sorghum bicolor were possible. One could suggest a decline in 'Opportunistic' cultivation given this scenario. However, this cultivation might persist just as the name 'Opportunistic' suggests, and perhaps just as a crop for fodder.

The implications of 'Opportunistic' cultivation for ancient floodplain or riverine agricultural systems are more significant. Given the number of riverine and floodplain agriculture instances in the world, this example of a specific type of cultivation of Panicum miliare potentially could be relevant to other situations. Of particular interest to the study of ancient agriculture is the absence of weeds in the floodplain deposits and in the subsequent crop fields. This affects the entire range of crop processing activities and the resulting patterning in the products and byproducts from each stage of processing. Ethnographic crop processing studies have been used to make inferences on the archaeological use of specific crops (Hillman 1981; Jones 1987; Reddy 1991). Such studies are based on the observations that each step of crop husbandry and grain processing has a measurable effect on the composition of crop products and byproducts. These effects are studied and 'cause-and-effect' models built for archaeological

interpretation. It is often the case that weeds are indicators of different stages of processing (Jones 1987). However weeds are generally absent in this study of 'Opportunistic' cultivation, due to the sterile nature of the clay flood deposits. Even when weeds are present, they are not incorporated into the crop processing activities. Furthermore, this type of 'Opportunistic' cultivation is particularly relevant for reconstructing ancient agricultural systems of the Nile, the Ganges and the Indus Rivers, all of which have seasonal flooding, and a long history of riverine and floodplain agriculture.

Specifically in a riverine system like the Indus, where there were major urban centers and smaller 'rural' settlements during the Harappan period (2500 - 2000 B.C.), such opportunistic, extensive cultivation is more likely to occur in the latter type of settings. Such cultivation, although practiced sporadically in the urban environs (probably by lower status groups), would have contributed minimally to the overall subsistence economy. The low yields per acre and the heavy time investment in crop processing would make it less attractive in the urban centralized market economy where intensive agricultural systems were more successful. 'Opportunistic' cultivation on the floodplains would be an attractive option in the rural settlements of the Harappan period, where there was a gradation between intensive and extensive agricultural systems. The degree of importance of animal husbandry would also be a contributing factor for the selection of such cultivation. In such cases, settlements optimally located near a floodplain could very well exploit the local floodplain opportunistically, thereby supplementing their subsistence resources for human consumption or animal fodder. Such cultivation would be particularly attractive for pastoralists who often grow quick maturing millet crops both for themselves and their animals.

'Opportunistic' cultivation though observed specifically in one river floodplain

in South India, has important ramifications for studies related to ancient agriculture, modern rural development and communal economic activity. With modernization, many traditional practices of crop husbandry discussed here are slowly being replaced by the mechanized agriculture of the 20th century, thus making studies of crop processing activities increasingly important for the further understanding of ancient agricultural and crop processing practices.

PROCESSING STAGES AND ARCHAEOLOGICAL INTERPRETATION

Even though the processing pathways are quantifiable in terms of compositions and specificity of distinctive variables, it is important to elucidate the likelihood of these stages being identified and discovered archaeologically. There are four aspects of each processing stage which need to be considered to define the archaeological relevance: storage (A), the probability of accidental burning at or before the processing stage (B), occurrence in domestic contexts (C), and the likelihood of preservation and survival into the archaeological record (D). Table 4.1 summarizes this classification.

Storage is an important variable, because storage of a crop product or byproduct (at any stage) increases its chances of accidental burning and survival into the archaeological record. Additionally, since storage is most often in domestic contexts the chances of discovery are increased. However, it is important to note that the storage index of a crop product or a byproduct is variable and constantly changing, but the general pattern remains. For example, a threshing product is given a storage index of 2, and it is possible that it could change to an index of 1 but never to 4 or 5, and in very rare cases to a 3. Survival into the archaeological record is based on whether there is carbonization of the different components of an assemblage through burning.

Table 4-1. Processing Stages and Their Archaeological Relevance

	A	B	C	D
Threshing Product	2	1	1	1
Thresh Byproduct	2	1	1	1
Winn I Product	3	1	2	2
Winn I Byproduct	1	1	2	1
Siev Product	5	1	4	3
Siev Byproduct	2	1	4	3
Winn (s) Product	5	5	5	5
Winn (s) Byproduct	1	3	5	4
Pound Product	1	4	5	5
Winn II Product	5	5	5	5
Winn II Byproduct	1	4	5	4
Grinding Product	5	5	5	1
Grinding Spillage	1	4	5	5

A: The processing stages at which products and/or byproducts are most likely to be stored

B: The probability of accidental burning occurring at the processing stage.

C: Likelihood of being in domestic contexts

D: Likelihood of preservation and discovery of products or byproducts of the processing stage in the archaeological record.

<u>Scales of Measurement</u>

1 (unlikely) 2 (25% chance) 3 (50% chance)
4 (75 % chance) 5 (highly likely)

Therefore, the probability of accidental burning occurring at the processing stage is very important, since this index determines which processing stages are by nature more discoverable in the archaeological record. The process that determines this index is roasting which occurs after sieving. The survival indices of the subsequent stages products and byproducts are therefore high.

Another factor which determines the carbonization rate of an assemblage is the likelihood of the processing occurring in domestic contexts. Domestic contexts are locales of intentional fires (cooking, heating etc) which increases the probability of accidental burning. Additionally, when a stage occurs in domestic contexts, there is a higher chance of the byproducts being included into contexts of burning or charring. Domestic areas are in general discovered more often archaeologically as compared to crop fields.

The crop products and byproducts of different processing stages were thus given indices to determine which assemblages are archaeologically significant.

Threshing product occurs away from domestic contexts and has a low storage index. Accidental burning occurring at this stage is unlikely and the assemblage is unlikely to be preserved and discovered archaeologically. The threshing byproduct has similar indices and is not significant for archaeological contexts.

Winnowing I (by wind) product has a relatively high storage index, but because of its low accidental burning index and the low chances of it occurring in domestic contexts, the survival and discovery of this assemblage is relatively low. Winnowing by wind byproduct is not stored and has a low accidental burning index, therefore its survival and discovery in the archaeological record is very unlikely.

Sieving product has a very high storage index, but it is not prone to accidental burning through the processing. However, it occurs most often in domestic contexts, and its archaeological discovery and survival is relatively high. The sieving byproduct is not

stored nor is it likely to be burned during the process. Yet since the process occurs most in home bases, the index of archaeological discovery and survival is high.

The winnowing by shaking products and byproducts are archaeologically significant, mainly because of the location of processing in domestic contexts. The winnowing by shaking product has a very high storage index and accidental burning index (because it is roasted before pounding), and its archaeological survival and discovery is very high.

The pounding stage is preceded by roasting and the pounding product also has a very high accidental burning index, and its archaeological survival and discovery is high mainly because of its domestic contexts despite of its low storage index.

Winnowing II (by shaking) product has very high indices for all the four variables, and this makes it a very significant assemblage for archaeological interpretations.

Grinding product has high storage and high accidental burning indices, and it occurs in domestic contexts. Archaeological survival and discovery is unlikely, however, since the product of grinding is flour which does not survive into the archaeological record.

Thus, it is apparent that the archaeological significance of the different stages is extremely varied, and these differences need to be considered when making archaeological interpretations.

SUMMARY

This chapter has demonstrated that there is a significant difference in processing pathways of the crops discussed. For example, sieving is very prominent in the processing of Type A crops but absent in the 'Opportunistic cultivation' of Type B

crops. Pounding is an important stage in the Type B processing but is of minimal importance for Type A crops. This variation is quantifiable since it creates distinguishable compositions within the byproducts and products. These differences in processing are a result of several factors including regional variation, type of cultivation, crop type, use of product and seed morphology.

Regional variation is important to consider, especially for archaeological interpretations. Even though Hillman (1984) and Jones (1987) argue for a limited number of ways for processing a plant, it is clear from this research that there are other methods (such as winnowing by shaking, pounding and grinding) that differ from previous observations made in traditional societies of Turkey and Greece. This regional variation in methods could be the result of historic developments. For example, Gujarat is closer to other culturally distinct regions of Pakistan and Afghanistan while Andhra Pradesh is more of a cultural island in peninsular India, and it has had less influence from outside sources. These differences could also be an expression of ethnically distinct groups who process materials a certain way to maintain group identity and ethnicity. These factors should be kept in mind when building models for archaeological interpretations.

I argue, however, that crop seed morphology plays the primary role in determining which processing method is chosen. This is particularly relevant in the case of winnowing. As discussed earlier in the chapter, winnowing can be done in two ways: by wind or by shaking (in an open wedge shaped basket). The exclusive choice of winnowing by shaking method for Panicum miliare was based on the small size of the crop seeds which would be lost through winnowing by wind. However, in the case of Sorghum bicolor and Pennisetum typhoides winnowing by wind was chosen as the first winnowing process (later followed by winnowing by shaking) because the crop seeds were not small and would not be lost during the process. Therefore, it can be

asserted that for archaeological applications, the winnowing choice is determined by the crop grain in question.

It is important to note that winnowing by shaking can be compared to Australian yandying as described by Cane (1989). Australian yandying involves a large wooden dish that is rocked and shaken in various directions at different angles to separate chaff and other rubbish. In general, yandying and winnowing by shaking are similar processes since both involve intensive processing through shaking, rocking and tapping, and produce similar compositions in byproducts and products. Cane (1989:105) suggests that yandying replaces winnowing and sieving of western Eurasian grain processing. Similarly, in the Panicum miliare processing pathway, winnowing by shaking replaces the winnowing by wind and sieving processes in the processing pathways of Sorghum bicolor and Pennisetum typhoides. This choice of winnowing method is a result of the crop seed morphology. In both the studies (opportunistic cultivation and summer cultivation), winnowing by shaking replaces the fine sieving stage present in the Near Eastern regions as described by Hillman (1984) and Jones (1987). This second situation, where winnowing by shaking replaces fine sieving, is a result of both ethnic choice and crop seed morphology.

The type of cultivation and the type of crop grown are also deciding factors in the processing. This research in India has clearly demonstrated this distinction. In 'Opportunistic' cultivation, the nature of the cultivation itself determines whether weeds are included and therefore the amount of processing done is minimized. In contrast, the inclusion of weeds is unavoidable in the Gujarat monsoonal cultivation, and the processing has to take this into account.

The type of crop being cultivated also affects the processing pathways. There are a variety of harvesting choices in Type A crops, such as Pennisetum typhoides and

Sorghum bicolor, as discussed earlier. The choice of harvesting affects the processing pathways regarding the inclusion of weeds, the amount of byproduct cleaning and the number of cleanings done at each stage. In Type B crops, such as Panicum miliare, there is no choice in harvesting method.

The seed morphology, whether it is a hulled seed crop as in Panicum miliare or a 'naked' seed crop as in Pennisetum typhoides and Sorghum bicolor, is a deciding factor for whether certain processing stages are needed or not. This is evident in the stages presented for each of these crops. For example, the dehusking process by pounding is not needed for Pennisetum typhoides and Sorghum bicolor, but it is an essential processing stage before consumption of Panicum miliare.

The next chapter presents the analytical results of the materials collected during these ethnographic studies, and the ethnographic modeling of crop processing for human food and animal fodder.

CHAPTER 5
ETHNOGRAPHIC MODELING

INTRODUCTION

This research project aims at isolating the distinguishing characteristics of crop processing activities and their archaeological implications. Ethnographic studies were conducted to address this question of millet crop cultivation in semi-arid to arid environment. This chapter presents the composition analysis of the ethnographic materials collected from processing stages of several millet crops. It also presents ethnographic modeling for the different crops studied, specifically the two types of crops: Type A and Type B (Figure 5-1). Finally variations in processing are modeled with respect to archaeological implications when crops are cultivated for three different purposes, for food only, for food & fodder, or only for fodder.

Kramer (1979) has explained that observations of contemporary behavior can facilitate the development and refinement of insights into past behaviors, particularly when strong similarities can be shown to exist between the environments and technologies of the past and contemporary sociocultural systems that are being compared. This is particularly true when one is considering the behaviors related to crop processing activities where the nature of processing is as much a factor of cultural tradition as it is of the morphological structure of the crop (Reddy 1991).

Ethnoarchaeological research investigates aspects of contemporary sociocultural behavior from an archaeological perspective; ethnoarchaeologists attempt to systematically define relationships between behavior and material culture patterning not often explored by ethnologists and, to ascertain how certain features of observable behavior may be reflected in the remains that archaeologists may find (Kramer 1979). Once such observations have been made, the ethnographic data can be used in a number

HARVEST METHODS

		I (cutting at top)	II (cutting at base)
CROP	A (summer cult)	Pennisetum, Sorghum	Pennisetum, Sorghum
TYPE	B (`Opportunistic' cult)	NONE	Panicum, Setaria

Figure 5-1. Harvest Methods and Crop Types

of ways. Stiles (1977) suggests three general uses for such data: ethnographic analogy, the generation of hypotheses or models, and lastly the testing of hypotheses. This project involves each of these uses and this chapter deals with the first two methods through ethnographic modeling.

Ethnographic modeling is the modeling of ethnographic data for archaeological interpretations through rigorous correlation studies and other data analysis. It entails the generation of hypothesis and models, ethnographic data being used as a source of information to generate these hypotheses and models about the past. Hypotheses, are generally postulated in response to the use of ethnographic information as a potential analogy to a specific archaeologically observed phenomenon, but they need not be. Models, on the other hand, seek to represent or describe a set of observed phenomena from the real world. A body of ethnographic observations may be combined to aid reconstruction and interpretation of a corpus of archeological data. From analogies made between the archaeological material of a particular site or 'culture' and the ethnographic parallels of a model, a selected segment of prehistoric life can be reconstructed.

The testing of hypotheses is essential, and this is done after the hypotheses have been formulated from ethnographic observation. If the pattern of the archaeological material fall within the range of variation of the pattern of the physical traces which

resulted from the ethnographic activity, one can then assume a certain probability that a valid analogy has been made. This degree of probability cannot be measured precisely, but the strong correlation of the two conditions should be indicative of an appropriate and viable analogy.

In this project, ethnographic materials were collected from all of the crop processing stages that were archaeologically relevant. Samples of threshing and pounding byproduct were not collected because the dominant components of these assemblages, such as chaff dust are not identifiable macroscopically. Secondly, the components of threshing byproduct, which include the straw and stalks, would not survive into the archaeological record as a distinct activity assemblage since they are given as fodder to cattle. The samples from archaeologically pertinent stages were analyzed for their compositions, and subsequently ethnographic models were built for the processing pathways of each crop.

In the subsequent sections of this chapter I will first present the section on general methodology and data analysis procedures. This includes a discussion on weed categories and crop types. The next section is the presentation of the data analysis of type A crops (summer cultivation of Sorghum and Pennisetum), and a model for their cultivation. The data analysis of type B crop cultivation without weeds ('Opportunistic' Cultivation of Panicum) and a model for their processing will be presented in the subsequent section. Data analysis and a model for the processing of wild plants such as Setaria tomentosa will be presented after the section on type B crop without weeds. The chapter will end with a summary and discussion of the three systems of cultivation: crops cultivated as food for humans, fodder for animals or as both.

METHODOLOGY AND DATA ANALYSIS

Harvesting of the study plots was done by farmers and farmer's aides who were

familiar with the processing activities. Each study plot was treated as an separate unit and studied in a similar manner. This facilitated computations regarding relationships between yield, proximity to water, byproduct compositions, and important differences of the compositions of the plots with known quantifiable differences.

The underlying premise for the analysis of the ethnographic samples was to identify and isolate distinguishing variables that are specific and distinctive to a particular stage or process. Therefore the main objective of the crop products and byproducts sample analysis is to establish the composition of each of these samples in relation to specific stage processing activities. All samples analyzed for composition were treated in a similar method. The major proportion of this initial analysis includes the basic documentation of assemblage composition from each processing stage. The samples were thus sorted and quantified for their compositions with specific attention being given to the range and quantity of weed species. To build models for archaeological applications, the identification of weed seed characteristics relevant to the different stages of crop processing are necessary. Therefore, during the analysis of the samples from each stage product and byproduct, special emphasis was placed on recording weed sizes, their tendency to remain in heads, their weights and their frequencies. Specificity of occurrence at a particular stage was recognized as an important variable, and an attempt was made to identify this during the data collection. Since weeds and crop plant parts are the main criteria for identification of crop processing stages in this study, careful attention was given to the selection of the different components for the data collection and composition analysis.

Materials collected during both the seasons of ethnographic fieldwork ('Opportunistic' cultivation in Andhra Pradesh and summer monsoonal cultivation in Gujarat) were analyzed to enable broad generalizations and comprehensive conclusions

about crop processing activities and patterning. Consistency was maintained throughout the study of ethnographic crop processing samples to facilitate comparative studies, both within this research project and with other studies.

The first stage in the analysis of each processing sample was sieving through three geological sieves: Sieve A (4mm), Sieve B (2mm) and Sieve C (.425mm). This was done to facilitate the identification of the variation in the physical sizes of the different components (such as rachillas without spikelets, rachillas with spikelets, specific weed species, and so on) for each stage's product and byproduct. Instead of measuring the size of each different component, distribution within the sieve sizes was used. First the volume of the sample was recorded, the three sieves were then placed on top of each other (with Sieve A on the top and sieve C at the bottom). The sample was poured onto the top sieve (Sieve A) in lots of 1 liter to minimize error through spillage and effective sieving. Once the samples was sieved the three sieve contents were collected separately in labeled bags and set aside for composition analysis. Therefore, for example, the 64 samples from Pennisetum typhoides processing stages collected in the field yielded 192 sub-samples (from the three sieves) for analysis.

In the next step of analysis, measurable amounts of the sub-samples were sorted into the distinguishable botanical categories. Thus each sub-sample was poured onto a open plate, and then the different components were sorted out and collected separately. After the sorting of a subsample was completed, the different components were quantified (actual counts, weights and volumes). After quantification, they were bagged, labeled and stored for future reference if needed. When relevant, the number of individuals in each category was counted. General observations of patterns and distributions were recorded during the process of sorting and measuring. Once the measurement and recording of the data were completed, the studied sub-samples were bagged, keeping the categories separate, and stored. These data obtained (actual

counts, weights and volumes) were standardized and then analyzed through quantitative and qualitative pattern searching.

In this study, the crop processing sequences are broadly divided into "higher processing stages" and "lower processing stages". Lower processing stages refer to the initial stages that occur in the fields and home bases. Additionally, in a non-mechanized and traditional economic system (such as the ones studied in this dissertation) when cultivation is geared to both household consumption and trade or exchange, the marketing of the crop products is done immediately after the lower processing stages. Higher processing stages refer to those stages which are closer to the consumption product or final product, and occur primarily in home bases or domestic activity areas. Importantly, when a crop product is intended for marketing (through trade or exchange) it is very rarely put through the higher processing stages. For example, the lower processing stages of a Type B crop (such as Panicum miliare Setaria italica) include threshing, sieving and winnowing I. Both sieving and winnowing I are most often done in the home bases while threshing is done in the fields. Trade or exchange of Type B crop products occurs after winnowing I in most instances. Higher processing stages of Type B crop include roasting, pounding, winnowing II and grinding. Often the later series of winnowing I are repeated just prior to roasting and pounding. The distinction between the lower and higher processing stages is significant specifically for ethnoarchaeological modeling in relationship to likelihood of archeological inclusion, survival and discovery, and very importantly the identification of cultivation versus trade and exchange.

The importance and significance of this methodology lies in its replicability and testability. Many of the components could at a later date be collapsed, but for this initial stage of composition analysis, all of the recognized components are the basic

elements of each sample. In the subsequent discussion, emphasis will be placed on the archaeological relevance of each component.

Weed Categorization

Samples of weeds were collected from the study fields during the summer monsoonal cultivation crop processing study in Gujarat. It was necessary to collect these weeds in order to have a comparative collection for the analysis of the harvested samples of the ethnographic products and byproducts. The weeds associated with the millet fields are particularly important since they may be indicative of the products and byproducts of different stages of crop processing. The weed collection was done in a systematic manner through initial reconnaissance of the fields followed by interviews with the farmer on weeds and their associations with the different crops. During the collection of the different weeds in the fields, notes were taken regarding their location (in terms of their association with a specific crop field), local common names used by the farmer and their general description. None of the weeds collected was from within the study plots, so as not to affect the frequency of weed plants being included into the crop processing stages. The plots, however, were scanned carefully to make sure that all varieties of weeds had been included into the comparative collection. The taxonomic identification of the weed samples was done through consultation with botanists (specially Ms. Charul Joshi) of the Laboratory of Environmental Sciences, Department of Biosciences, Saurashtra University.

Previous ethnographic studies conducted by Hillman (1984) and Jones (1987), particularly designed to model for archaeological interpretations, used weeds as indicators of different crop processing stages. Jones (1987) used weeds more exclusively than Hillman (1984, 1985). Through their studies of present day crop products, they argued that the principal factors determining what seeds were present in

any one crop product were: (i) the ratio of their surface area to weight (their winnowability); (ii) seed size (sievability); and (iii) seed 'headedness'. Thus each weed species present in the crop processing stages was characterized in terms of these three variables.

Hillman (1984, 1985) stated that winnowability, the probability that a seed can be winnowed out of the prime products, seems to depend primarily on the ratio of its surface area to weight. Therefore, the bigger and heavier a seed the lower the probability of being winnowed out (i.e, a lower winnowability). The presence of dispersal appendages such as hairs or wings increases a seeds winnowability.

Sievability is dependent on seed size, and there is a clear correlation between sievability and winnowability, as also determined by seed size/weight ratio. Hillman (1985) groups seeds and fruits into four sievability/winnowability classes, each of which is characteristic of a single class of crop product. Therefore, he argues that in the absence of mixing, the identification of these particular products is very straightforward. The classification of weeds into the four classes is based on weed sizes. These are not absolute sizes, but relative to the width of the primary spikelets of the wheat crop. This classification is not relevant to millet processing, since most of the millet crops being considered in this study are of different size and shape when compared to wheat.

Headedness is the measurement of a weed seed being contained on a head (or panicle), and often the weed seed is released from the head only after a certain stage of processing. This is particularly true if the weeds are immature at the time of harvesting. Hillman and Jones both argue that theoretically the two parameters 'winnowability' and 'headedness' should not be used independently.

Jones (1983) employs a similar weed classification with the size of the weed

seed being relevant for fine sieving processes; the tendency of weed seeds to remain in heads, spikes or clusters despite threshing, being relevant to coarse sieving, and the aerodynamics/ winnowability being most relevant to winnowing.

For this project, where the crops being studied are the millets, Sorghum, Pennisetum, Panicum and Setaria, the weed classification of Hillman and Jones had to be modified. Modification was necessary not only because of the different crops being studied, (which affected the weed size categories made by Hillman and Jones), but also because the processing stages and methods were significantly different. For example, Hillman's crop processing stages included a fine sieving stage which was absent in the crop processing pathways studied in this project. Sievability was an important factor for Hillman to consider, but in this project it is not of such critical importance. Similarly, an additional stage (winnowing by shaking) was observed in this project but was absent in Hillman's crop processing studies. In this study a winnowing basket separates crop products and byproducts through shaking, tossing, tapping and hand sorting; seed headedness, seed weight and seed size are all of equal importance in this winnowing stage.

The weed classification developed in this project incorporates some of Hillman and Jones's criteria for the selection of factors effecting the presence of seeds in the crop products. In addition, criteria which were more relevant for millet crop processing (with respect to both the crop and the processing methods) were used to develop a classification. This classification does not use terminology that is implicative of a stage (as suggested by the classification terms of Hillman and Jones - Winnowability, Sievability). Instead it uses attributes of the weeds that can have implications at various stages depending on the processing pathway and what the processor is selecting for specifically. Therefore, this classification is not dependent on stages, but rather concentrates on the attributes of the weeds and the processing method. For example,

whether a seed is winnowable or not is irrelevant, because winnowability (through shaking) is not dependent on one characteristic, but a combination of characteristics. One of the main advantages of this classification is that it does not use weed size relative to crop seed dimensions; therefore, the classification also can be used in the future for other crop types.

During the analysis, all the weeds collected were classified into size, seed headedness and weight/aerodynamic categories which were then used to classify the weeds into distinct categories. Each category, its significance in the crop processing activities studied in this project and the method of categorizing will be considered in the following discussion.

(i) Size: Size is an important variable because it is often the first discriminating factor used to select against non-crop seeds (i.e., weeds). The bigger the seed the higher the probability that it will not be present in the latter stages of processing. However, size is not an independent variable, since the combination of size and weight is often the determining factor. It is nonetheless important to note that winnowing by wind tends to eliminate very small seeds whose weight is not a controlling factor. Seed size also affects sievability as argued by Hillman (1984). However, in this project sieving was very coarse and aimed more at the separation of very large non-crop seed components, such as unthreshed/immature inflorescence heads, large spikes and stalks. This coarse sieving, does not separate out weed seeds of any size efficiently. Seed size is a determining factor in winnowing by shaking but unlike winnowing by wind there is more control on selection. Even small seeds can be selected for retention in winnowing by shaking, just by altering tapping, shaking and hand sorting movements and eliminating tossing. Therefore, seed size is not the sole discriminating factor in winnowing by shaking.

Weed seed size was determined through the use of geological sieves. As discussed earlier in this chapter all samples to be analyzed were first sieved through three geological sieves: Sieve A (4mm), Sieve B (2mm) and Sieve C (.425mm). This was done to facilitate the identification of size variations in different processing stages. Weed size categories were then formulated using these three sieve sizes and the ethnographic sieve used in the crop processing. The size categories range from very small to very big, and coded from 1 for very small to 5 for very big:

Size category 1: < .425mm (falling through Sieve C)

Size category 2: > .425mm but < 2mm (staying in Sieve C)

Size category 3: > 2mm but < 4mm (staying in Sieve B)

Size category 4: > 4mm but < 7mm (staying in Sieve A)

Size category 5: > 7mm (staying in ethnographic Sieve)

Each weed species was thus categorized into the appropriate size category depending on which sieve it was primarily associated with. Size categories 1 and 2 were classified as small, while size categories 4 and 5 were classified as Big. None of the weeds were predominantly in size 3 category. Therefore classification of the weeds in category 3 was done by relating it to the immediate preceding and succeeding sizes of 2 and 4. For example, <u>Aristolochia</u> <u>bracteolata</u> occurs most significantly in size category 2, and in lower numbers in size category 3, therefore, the final size was determined to be small.

(ii) Headedness: The tendency of weed seeds to remain in heads, spikes or clusters in spite of threshing is an important variable to consider in classifying the weeds. The tendency to remain in heads is a result of the degree of immaturity of the weed plants at the time of harvest. A high tendency for headedness results in distinct processing patterns. It is quite common that when weed seeds are headed they are less winnowable by wind, and are most effectively removed from the crop product through

winnowing by shaking. Headed weeds are not always processed out during sieving because the ethnographic sieve is large enough for the headed seeds to pass through (the main purpose of the ethnographic sieve being to separate out larger non-crop components such as straw, inflorescence heads, stalks). In sum, headedness makes a weed seed larger and more visible for processing out during the winnowing by shaking, and subsequent stages.

The measurement of 'headedness' much like the next variable 'aerodynamics/weight' is a more subjective measure than that of weed sizes. 'Headedness' was classified on a scale of 1 to 5, where 1 was very likely to be free and 5 was very likely to be headed. The weeds were rated according to where on the continuum they fall, and this was decided primarily through comparative observations between each other, and in addition observations on how they appeared in the processing stages: for example if they continued to appear headed in the later stages despite the threshing and sieving that could have dislodged their headed nature.

(iii) Weight/Aerodynamics: This characteristic is of importance in winnowing processes rather than sieving, though if seeds are particularly small and heavy they could pass through the sieve with more ease than if they were light and small. Additional appendages are of considerable importance in the determination of aerodynamics. However there were a only a few weeds in this assemblage that had aerodynamics appendages such as hairs, wings or equivalent dispersal mechanisms.

This variable was measured by utilizing data on weight, shape and aerodynamic appendages of the weeds. Therefore it is a classification which is the result of the three measurements. Weed seed weight is important for evident reasons; the heavier the seed the less its aerodynamics and vice versa. Weed seed shape is considered significant because it effects the processor's discrimination due to any similarity to the crop seed.

The higher the similarity in shape and size, then the greater the chances of such weed seeds not being processed until the later stages where hand sorting is predominant. The weed seeds are scored on a scale from 1 to 5, with 1 being very light and highly aerodynamic and 5 being very heavy and with low aerodynamics.

(iv) Conclusion: Using the three main characteristics presented in the above discussion, seed size, seed headedness and seed aerodynamics, the weeds from the ethnographic studies of this project were classified into 8 categories:

Small Free Heavy (SFH)	Big Free Heavy (BFH)
Small Free Light (SFL)	Big Free Light (BFL)
Small Headed Heavy (SHH)	Big Headed Heavy (BHH)
Small Headed Light (SHL)	Big Headed Light (BHL)

The weeds were grouped into these categories and used for the modeling of the ethnographic crop processing pathways.

Crop Types

The underlying premise of the ethnographic crop processing studies conducted in this project was that each step of crop husbandry and grain processing has a measurable effect on the composition of crop products and by products. This same ethnographic research has confirmed that the wheat/barley/pulse models of crop processing developed by Hillman (1981, 1984) and Jones (1983, 1984, 1987) are not applicable for millet crops such as Sorghum, Pennisetum, Panicum or Setaria that are addressed in this project. One of the major differences between these two groups of crops lies in the harvesting methods.

Millets crops such as Sorghum, Pennisetum and Eleucine are harvested in several different ways. One of the distinctive methods, termed the Type I method is by only cutting off the inflorescence heads and leaving the stalks behind. This initial

variation in processing has a measurable effect on the composition of crop products and byproducts, primarily in the inclusion of weeds. Crops that can be harvested in this manner have been classified as Type A crops (see Figure 4-7).

Other millet crops such as Setaria spp. and Panicum spp. are termed as Type B crops (small grained plant crops such as Chenopodium spp. can also be included into this type). Their harvesting method includes the inflorescences heads, the stalks, and most often they are cut at the base of the plant (see Figure 4-2). This method, Type II, incorporates the weeds growing in between and around the crop plants into the processing stages. These weeds then appear in the crop products and have to be methodologically removed through various processing methods. Thus the compositions of the different stage crop products and byproducts is markedly different from Type A Crop processing.

It is important to keep in mind the distinction between Type A and B crops and Type I and II methods of harvest. Type A crops can on occasion be harvested as a Type B crop, but Type B crops are very rarely or almost never harvested as Type A crops (Figure 5-1). Therefore, there is a higher probability that Type B crops products are more likely to contain weed seeds than Type A crops. Furthermore, when weed seeds occur in Type A crop products then, depending on their frequencies they are anomalous intrusives or the Type A crop was harvested like Type B crop.

This distinction made between crop types based on harvesting method is important because this first crucial step in the processing has a critical effect on the crop products and byproducts compositions of successive stages. It is therefore important to understand the effect this harvesting event has on the process for each crop and for different ecological regions. When there is variation in crop product compositions within and between different ecological areas (specially in terms of

absence or low weed inclusions) it is important to determine the reasons for these variations. The harvesting method should be the first indicator, albeit initial, before pursuing explanations such as effects of processing methods or ecological factors.

TYPE A CROPS: SUMMER CULTIVATION OF *Sorghum bicolor* AND *Pennisetum typhoides*

Introduction

The objective of the ethnographic crop processing study in this dissertation is to isolate the variables that identify millet processing for human food, both as human food and animal fodder, or in rare cases as only for fodder. My ethnographic observations in Gujarat, India, have noted that millets are rarely grown solely as fodder, and it is only in very rare instances that millet grain are fed to animals as fodder. Similar practice may be possible for the Harappan situation. Typically the grain is used for human consumption, while the byproducts (the crop residues) are used as animal fodder. In some instances, typically where fuel sources are infrequent millets are grown only as human food, and the residues are used as domestic fuel and these are often the only source of fuel. This is generally the situation when the number of animals owned by the farmer is relatively small, and they can be supported by free-range grazing.

In Gujarat, the primary millets grown by both the farmers and pastoralists are *Sorghum bicolor* and *Pennisetum typhoides*. The crop byproducts from these crop harvests and processing are fed to cattle. Occasionally *Panicum miliare* is also grown as green fodder for cattle. Green fodder is preferred for dairy animals, due to its low fiber content and high protein.

As presented in chapter 4, the ethnographic crop processing studies of summer monsoonal cultivation of millet crops took place in the settled village of Babarkot in

Bhavnagar District, Gujarat. The two millet crops chosen for the study were those of Sorghum bicolor (Jowar) and Pennisetum typhoides (Bajri), both of which are Type A crops (Reddy 1991b). This research has attempted to examine whether Hillman (1984) and Jones (1987) 14 processing stages distinguished for free-threshing cereals and pulses are applicable to millet processing. During this study, emphasis was particularly placed on documenting the cultivation of millets and their ultimate use, and the research was designed to quantitatively discriminate the variables that correlate the cultivation of millets with their ultimate use.

The study plots selected in the fields of Pennisetum typhoides were three 5 X 5 meter squares, and the plots in the Sorghum bicolor fields were two 5 X 5 meters squares (Figure 4-4). The plots were characterized as follows: P1 (close to a water channel, cattle shed, pathway and field of cotton and Sorghum bicolor); P2 (most isolated, furthermost from cattle, pathway, another crop field); P3 (furthermost from water channel and cattle), S1 (closer to water channel, cattle, pathway and another crop field); and S2 (further from water channel, cattle, pathway and another crop field) (see figure 4-4). The importance of these criteria is twofold: the variation of weeds and other components could be correlated to these different variables; secondly, and more importantly, having plots which satisfy all these different conditions provides a more representative sampling of the field for the study.

Sorghum bicolor

Sorghum bicolor is an annual with a erect solid stem and a compact inflorescence head at the top of the stem. The more or less compact panicle has an axis or rachis of variable length (Cobley 1956). Sorghum bicolor has paired spikelets borne on rachii at the tips of branched stiff rachillas (Figure 5-2). The maturity of the

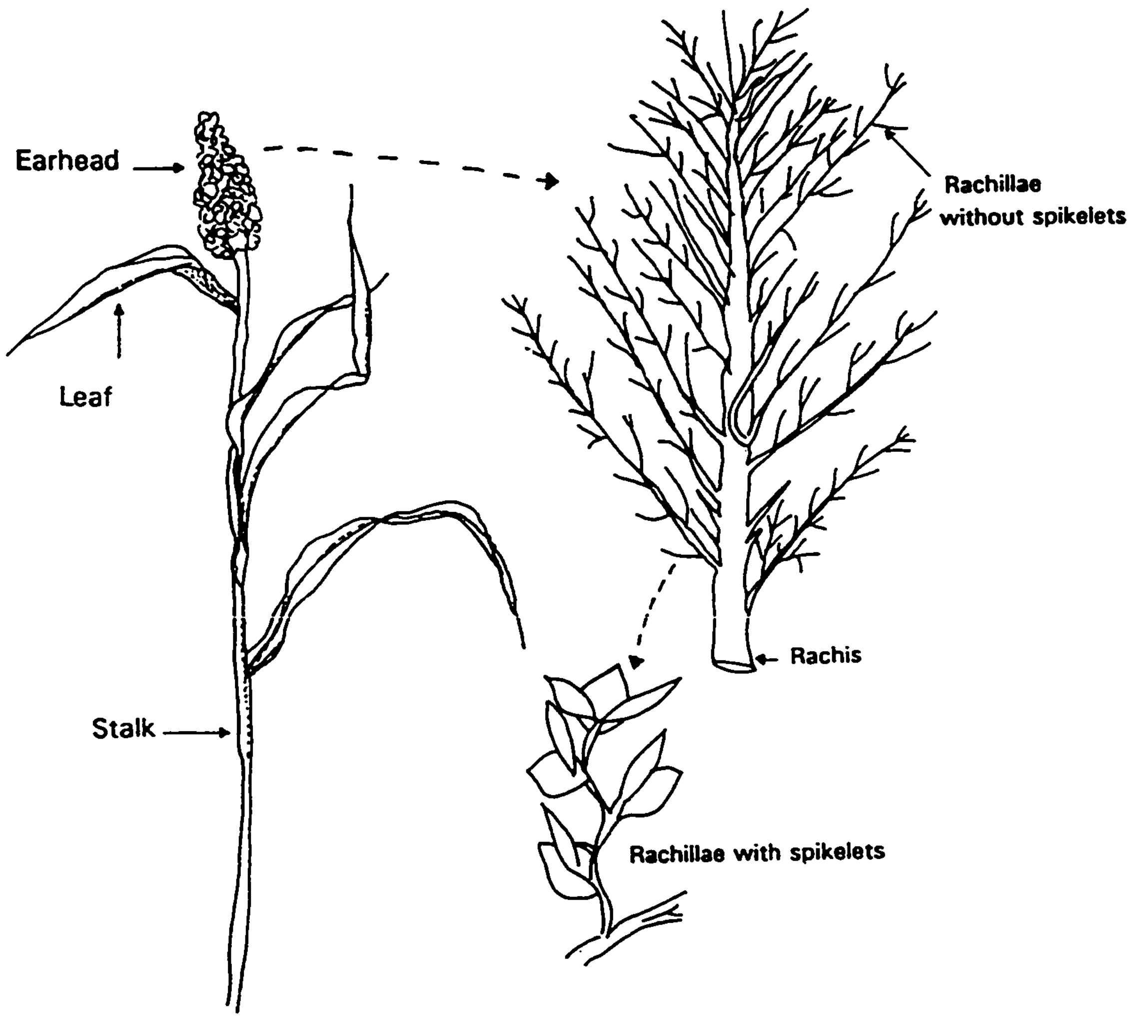


Figure 5-2. Sorghum bicolor Plant Showing the Major Components

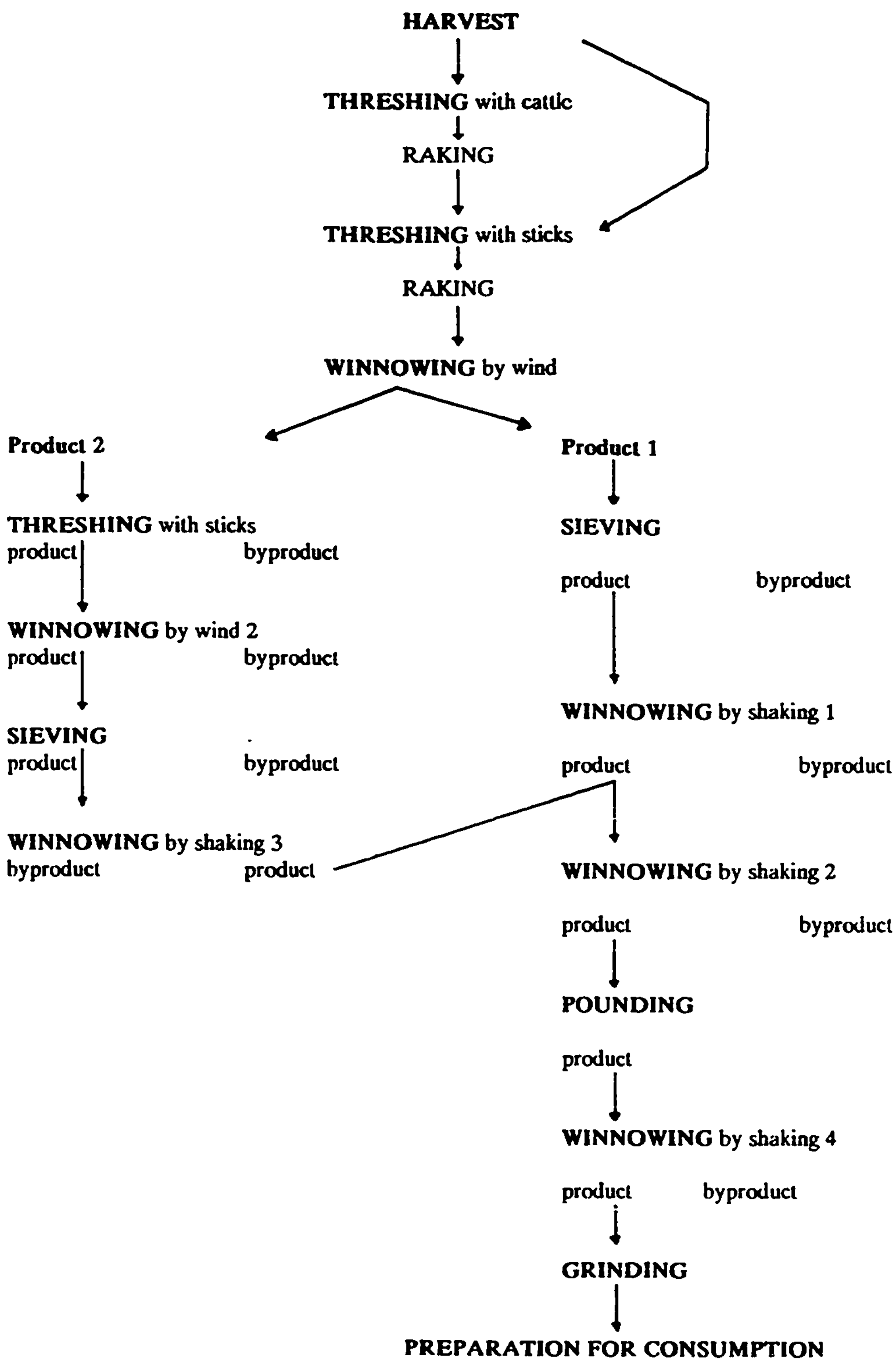


Figure 5-3. <u>Sorghum bicolor</u> Processing Pathway

inflorescence head starts at the apex and continues downward. The caryopsis is rounded and varies in shape and size. It is comparable to naked wheats, since it comes free of the palea and lemma without much threshing, although occasionally one does not get freed. The major components identified during the composition analysis of the Sorghum bicolor samples are: inflorescence heads, straw, chaff, Sorghum bicolor seeds with husk, Sorghum bicolor seeds without husk, Sorghum bicolor rachillas with spikelets and a range of weed species (Figure 5-4, Table 5-1).

The data collection and analysis was a two step process. During the first step, a subsample was examined and by sorting through the materials the different categories were formed. These categories were based on the botany of the plant. It is assumed that the categories most distinguishable from the caryopsis are processed out earlier in the processing stages, while those that are most similar to the caryopsis are processed in the later stages.

The second step involved the recording and documentation the frequencies, weights and volumes of these categories (wherever appropriate). As a result of this composition analysis, several general observations can be made of the Sorghum bicolor samples.

General Patterns

Significant differences were observed between the two Sorghum bicolor plots, S1 and S2. The main differences lie in the amounts of straw, inflorescence heads (panicle heads) and the types of weeds.

Straw is present in both plots but not in all the stages of the two plots. In plot S2, it is absent only in winnowing by shaking product, while in plot S1 it is absent in sieving product, winnowing by shaking product and winnowing by shaking byproduct. It is important to note that the straw in plot S2 sieving product, winnowing by shaking

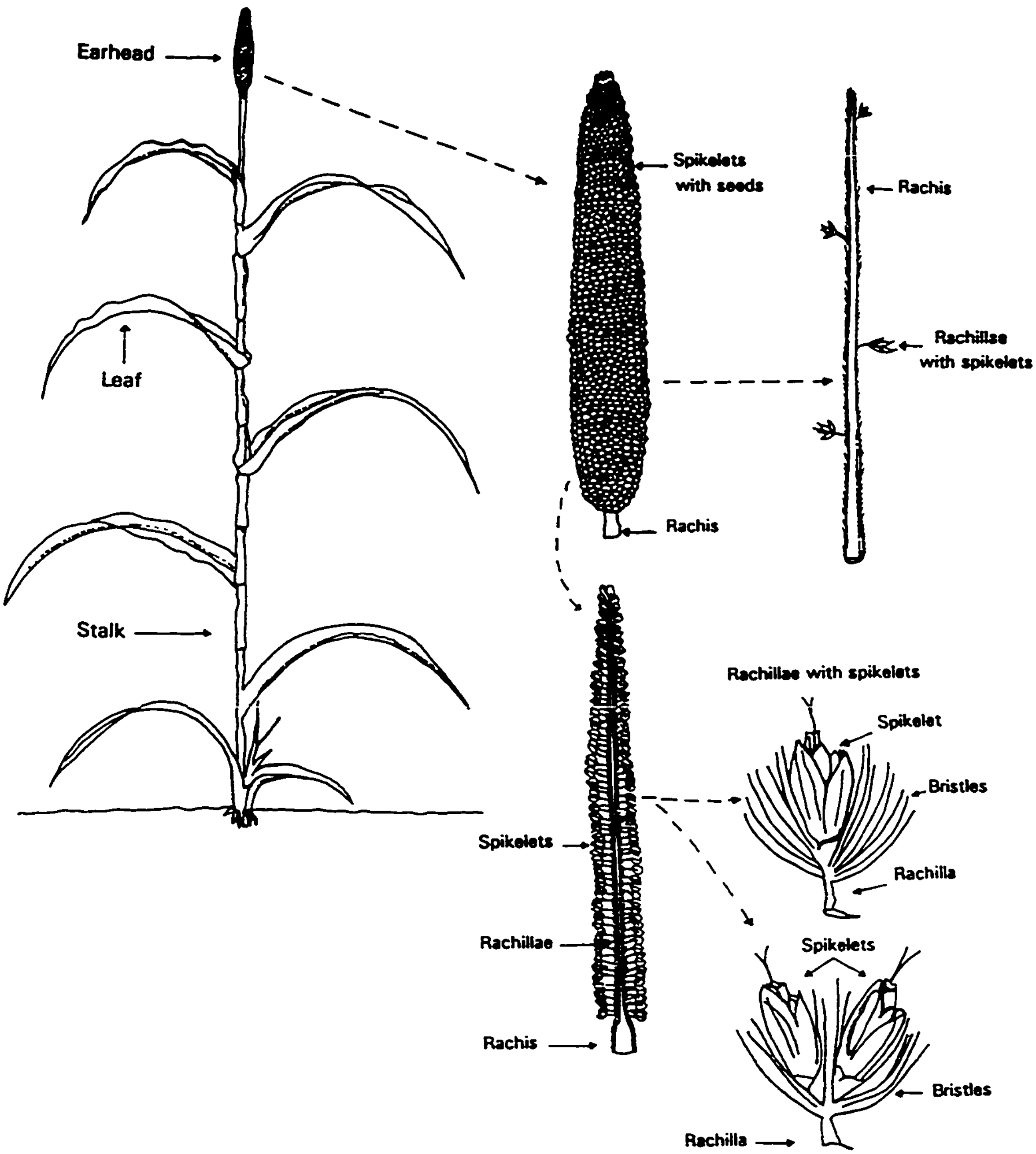


Figure 5-4. Pennisetum typhoides Plant Showing the Major Components

Table 5-1. Standardized Data of Sorghum bicolor Plots Combined

Standardized Counts for Sorghum
(per 500 gms for each stage)

	Th Prod	Win(w)Pdt	Win(w)Byp1	Win(w)Byp2	Siev Pdt	Siev Byp	Win(s)Pdt	Win(s)Byp
Straw Vol (ml)	27623	1163	68170	288892	1213	4744		4333
Sorg. rachillas w/spks	2134	21631	1214	3140		107632		
Sorg.infl.heads	328	43	813	556		157		
Sorg.w/husk	26622	41654	4946		23467		25743	106978
Sorghum grain	13882	38401	375		28928	2369	17924	7937
Sorghum Rachis					121			
Weeds (#)	78551	98955	8495	30448	118139	4916	815	332848
Amaranthus sps (SFH)	1290	669	208	54	1282			3986
Carvia sps (SHH)		90	312					
Chloris sps (BHL)	16		181	979		13		
Dactvloctenium spks (SHL	1393	305	3244	8411	30	1748		81
Dactyloctenium sps (SFL)	35851	35590	322	771	50467	372	96	203866
Digera sps (SFH)	2073	1674	351	326	2680	2030	329	11082
Digiteria sps (SFH)	892	61	279	5536	122	120		
Eragastis sps (SFL)	5286	5139	1513	4309	3641	193		8837
Eragastis spk (SHL)	43	61	363	1087		139		
Eremopogon spk (SHL)	16		62					
Eremopogon sps			87					
Hieracium sps (SFL)					212			
Hylandia sps (SFH)	39	20	21			50	6	
Indigofera sps (SFH)	47							
Iseilema sps (SHL)	16		58	165		52		
Paspalum sps (SHH)	8						300	
Phyllanthus sps (SHH)	16	73		81	334	39		261
Setaria tomentosa (SHH)	30913	54053	896	7192	57642			95789
Setaria tomentosa spks	47		125	597				
Trianthema sps (SFH)	471	1131	125		1447	13	36	8660
Trian.w/rachis (SHH)	16				242		48	245
Triumfetta sps (BHH)	8							
Vernonia sps (BFL)	110	89	348	940	40	147		41
Total SFH Weeds	4812	3555	984	5916	5531	2213	371	23728
Total SFL Weeds	41137	40729	1835	5080	54320	565	96	212703
Total SHL Weeds	1468	366	3814	9663	30	1939		81
Total SHH Weeds	31000	54216	1333	7870	58218	39	348	96295
Total BHL Weeds	16		181	979		13		
Total BHH Weeds	8							
Total BFL Weeds	110	89	348	940	40	147		41

Key

Threshing Product = Th Prod
Winnowing (w) Product = Win(w)Pdt
Winnowing (w) Byproduct 1 = Win(w)Byp1
Winnowing (w) Byproduct 2 = Win(w)Byp2
Sieving Product = Siev Pdt
Sieving Byproduct = Siev Byp
Winnowing (s) Product = Win(s)Pdt
Winnowing (s) Byproduct = Win(s)Byp

SFH = Small Free Heavy
SHH = Small Headed Heavy
SFL = Small Free Light
SHL = Small Headed Light
BFL = Big Free Light
BHH = Big Headed Heavy
BHL = Big Headed Light

product, and winnowing by shaking byproduct is only of sieve C size. These patterns indicate that in plot S1 the straw was processed out efficiently in winnowing by wind and sieving, but in plot S2 the straw is not processed out until the next stage down the line, i.e. winnowing by shaking. The efficiency of the processor is not the reason for these differences since the same processor did both plots in this study. More probably plot S2 was drier at the time of harvest, since this plot is further from a water channel. Thus since it was drier there was more breakage of the plant material (straw in this case) during threshing by sticks. This resulted in more sieve C straw not getting processed out in the earlier stages mainly due to its smaller size.

The other difference between the two Sorghum bicolor plots lies is in the distribution of inflorescence heads between stages. The inflorescence heads occur in the threshing product, winnowing by wind product, winnowing by wind byproduct 1, and sieving byproduct in both the plots. In addition, the inflorescence heads also occur in Sorghum bicolor plot S2 winnowing by wind byproduct 2. Winnowing by wind byproduct 2 is the lighter of the two byproducts and is often processed through several stages to retrieve the crop grain in the byproduct. The presence of the inflorescence heads in the winnowing by wind byproduct 2 of Sorghum bicolor plot S2 is because these inflorescence heads are the immature and the smaller sized ones which are lighter and become included into this byproduct. The presence of these smaller inflorescence heads in plot S2 also may be because this plot was further away from the water channel, and this had a direct effect on the growth and maturity of the inflorescence heads.

The last difference between the two plots entails variation in the distribution of weeds between processing stages. Specific weeds found in one plot are absent in the other, and vice versa. The weeds were categorized to determine if there were any patterns of occurrence according to the categories, but there was no correlation. The

most important observation is that weeds decrease significantly through the processing pathway and there is a definite patterning in their occurrence that can be used as indicators of different processing stages.

Finally, Sorghum bicolor seeds with husk are present in relatively high frequencies through the processing stages studied in this project, and indicate that the processing is not a simple elimination activity, but a process where conscious attempt is made to increase yields, and to maximize the retrieval of the Sorghum bicolor grains both with and without husk during processing.

The processing pathway of Sorghum bicolor is not a simple linear route, but it is an involved process in which decision making plays an important role (Figure 5-3). This decision making is based on the experience of the processor, and also general factors such as amount and nature of the plant material being processed, economic needs and cultural systems. For example, decision making is important to decide whether to select a winnowing by wind byproduct for further processing or to use as fodder. Also, decision must be made on when a byproduct can be used as fodder (both immediate or stored), or large enough in quantity to become stored fodder.

Detailed Analysis

After the samples were sorted and categorized, the data were analyzed to identify patterns that relate to the different processing activities and to isolate variables which are indicative of a particular processing activities.

In the analysis process, the first step was to standardize the data to facilitate rigorous comparison between all the plots (including data from different crops such as Panicum miliare and Pennisetum typhoides). The standardization was based on weight rather than volume since volume measurements of some of the ethnobotanical materials

such as straw, chaff whose volumes is unreliable and inaccurate. For example, S1 threshing product weighed 26 gms and was then standardized to 500 gms, and then all other components were accordingly standardized to 500 gms of the total threshing product. Standardized data were then used for pattern searching for the main data analysis (Table 5-1).

In order to search for patterns and isolate variables that distinguish processing stages products and byproducts, the standardized data from both the Sorghum bicolor plots S1 and S2 was first combined and then studied. This combining was done to provide a more representative data set, since between the two plots all the ecological variables identified in the field are included. Additionally, since there were no major unexpected differences between the plots, apart from the ones already presented, combining the two data sets was appropriate. The results of the analysis and pattern searching will be presented and discussed in the following order: straw, inflorescence heads, Sorghum bicolor rachillas with spikelets, Sorghum bicolor seeds with husk, Sorghum bicolor seeds without husk, and the weeds categories.

Straw

The straw component is present in significant amounts in threshing product, winnowing by wind byproduct 1 and byproduct 2 (Table 5-1). The assemblages from these stages are also characterized by dominant amounts of Sorghum bicolor inflorescence heads. It is important to note that these two components are not viewed as strong isolating variables, since their archaeological preservation and discovery is quite unlikely. Straw also occurs in moderate amounts in winnowing by wind product, sieving product, sieving byproduct, and winnowing by shaking byproduct.

Winnowing by shaking process removes out all the remaining straw from the crop product which was not processed out in any of the earlier processing stages (Table

5-1). Observations on the relationship between sieve size and the straw component patterning reveals that the higher in the processing stage the lower is the sieve size; in other words in the higher processing stages there is no sieve A straw and most straw occurs in sieve C. This pattern is expected since the processor is more likely to remove larger undesirable components in the earlier stages and the smaller ones later.

Inflorescence Heads

Analysis of the distribution of the inflorescence heads of Sorghum bicolor reveals that they dominate the winnowing by wind byproducts 1 and 2, and the threshing product (Table 5-1). They occur mostly in sieve A, and they only occur in sieve B in winnowing by wind byproduct 2 from Sorghum bicolor plot S2. The inflorescence heads occur in moderate amounts in sieving byproduct and in much lower numbers in the winnowing by wind product. The implications of this pattern is that the Sorghum bicolor inflorescence heads are processed out in significant numbers in the winnowing by wind process, and the remaining small quantity is processed out through sieving. Thus, Sorghum bicolor inflorescence heads can be used as a variable to isolate the lower processing stages such as threshing and winnowing by wind.

Sorghum bicolor rachillas with spikelets

This distint component occurs dominantly in the sieving byproduct (Table 5-1). They occur in moderate to lesser amounts in the winnowing by wind product, threshing product, winnowing by wind byproducts 1 and 2. They are absent in the sieving product, winnowing by shaking product and byproduct. This patterning shows that the Sorghum bicolor rachillas with spikelets are quite discriminating in their occurrence and could be used as a relatively strong distinguishing variable, particularly for the

sieving byproduct stage.

Sorghum bicolor seeds with husk

This component occurs in very dominant numbers in winnowing by shaking byproduct (Table 5-1). They occur in dominant frequencies in threshing product, winnowing by wind product, sieving product, and winnowing by shaking product. Although the bimodal distribution appears anomalous at first glance, it can be easily explained. The seeds with husks dominate the crop products of different processing stages showing that they are being chosen purposefully in spite of them being husked (these grains will have to be dehusked specifically later). The very dominant frequencies in the winnowing by shaking byproduct however, is due to removal of seeds that are defective and infected. They are processed out only during the hand sorting activity in the winnowing by shaking process. This patterning also reveals an attempt to limit loss of Sorghum bicolor grain since the processor is making a strong effort not to remove the seeds with husk, but to invest labor in dehusking them at a later stage (but before the seeds are to be pounded or ground). These Sorghum bicolor seeds with husk are often then separated from the dehusked ones and then husked through light pounding followed by winnowing by shaking to separate the chaff from the seeds. Then these seeds are combined with the other Sorghum bicolor dehusked seeds.

Sorghum bicolor seeds without husk

The seeds without husk occur in varying frequencies in all the stages crop products and byproducts except winnowing by shaking byproduct 2 (Table 5-1). They occur in lesser frequencies in winnowing by wind byproduct 1 and sieving byproduct. As expected they occur in highly dominant frequencies in threshing product, winnowing

by wind, winnowing by shaking products, and sieving product. Winnowing by shaking byproduct also has them in moderate amounts, as a result of intentional removal by shaking and hand sorting rather than accidental processing loss. Their presence in such moderate amounts is important, since the winnowing by shaking occurs in domestic contexts where the index of archaeological discovery and preservation is relatively high.

Weeds

Weeds in the Sorghum bicolor plots are present in relatively high frequencies in all the stages products and byproducts, except in sieving byproduct and winnowing by shaking product (Table 5-1). The weed categories present are small headed heavy (SHH), small headed light (SHL), small free light (SFL), small free heavy (SFH), big headed heavy (BHH), big headed light (BHL) and big free light (BFL). Only the weed category of big free heavy (BFH) is not represented. Of all the categories, the small free heavy (SFH) weeds are the most ubiquitous, followed by the small headed heavy (SHH) and small headed light (SHL). The big sized weed categories such as the big headed heavy (BHH), big headed light (BHL) and big free light (BFL) occur in low frequencies, while the small sized weeds have significantly higher in frequencies. The ratio of headed to free weed seeds is equal showing that both types of weeds occur in the processing stages, and the key question is where they drop off from the crop products within the pathway.

The patterning of the weed categories down the processing pathway is intricate in that different categories occur in differing numbers at different stage products and byproducts. Weed categories are processed out at different stages due to their morphological characteristics. For example although most weeds are processed out by

winnowing by shaking, some of the SHH, SFH and SFL category weeds remain, albeit in extremely low frequencies, in the winnowing by shaking 1 product. The SHL weed category however is primarily processed out by sieving, and the remaining SHL weeds are removed by the winnowing by shaking process. The BHL category of weeds are processed out first in limited numbers through in winnowing by wind and then primarily by sieving. The BFL weeds are processed out through sieving. Thus distinct categories of weeds occur in varying levels of significance at different processing stages, and therefore they can be used as indicators of these processing stages crop products and byproducts. It is important to emphasize that they alone cannot be used as discrete isolating factors. Instead a combination of specific weed categories ratios and other components, such as crop grains with or without husk or rachillas with spikelets, must be used to successfully identify assemblages relating to the crop products or byproducts of different processing stages.

Summary of Sorghum bicolor

In summary several strong observations can be made regarding the distribution of the various components in the crop products and byproducts. These observations have important implications for modeling the discrimination of crop processing stages for archaeological interpretations.

Sorghum bicolor inflorescence heads are definite indicators of lower processing stages such as threshing and winnowing by wind, but they cannot be used as the exclusive isolating variables for archaeological contexts since they are unlikely to preserve in the archaeological record. For archaeological contexts, the preservation of panicle heads and their discovery is mainly dependent on whether they are carbonized or not. There are two critical factors that determine whether this component is archaeologically important as a strong isolating variable; the location of the processing

activities and the likelihood of the components being exposed to fire. Threshing and winnowing by wind most often occur in fields/non-domestic contexts which are unlikely to be discovered archaeologically, and their preservation in such contexts through exposure to fire is unlikely. Thus, the Sorghum bicolor inflorescence heads though good indicators of threshing and winnowing by wind, have a lower index of significance as an isolating variable (Table 5-1).

Sorghum bicolor rachillas with spikelets can be used as distinguishing variables, since they occur in dominant frequencies (as compared to other components) only in the sieving byproduct (Table 5-1). Clearly rachillas with spikelets were being processed out by sieving, resulting in the high frequencies in the sieving byproduct. They occur in low and moderate frequencies in the threshing and winnowing by wind assemblages, and are absent in the sieving product and winnowing by shaking assemblages. Therefore, when an assemblage is dominated by Sorghum bicolor rachillas with spikelets, this is a strong indicator of a sieving byproduct assemblage.

Sorghum bicolor seeds with or without husks are important indicators of crop products from all the stages (Table 5-1). When seeds dominate an assemblage, then it can be certainly interpreted as a crop product. However, Sorghum bicolor seeds with or without husk alone cannot be used to determine the particular processing stage of the crop product. In conjunction with other components, the stage can be distinguished. For example, if the relative proportions of Sorghum bicolor seeds (husked or/and dehusked) is much higher than other components, ranging from the majority to total dominance, then the assemblage could be interpreted as representing a winnowing by shaking 1 or 2 product. Once again it is important to emphasize that typically one component cannot be used as a singular isolating indicator or variable.

Weed categories are also important distinguishing variables. In conjunction with

other components they provide signatures of assemblages relating to different stages products and byproducts. It is important to consider how the different weed categories interplay with the different processing activities. For example, the headedness of a weed has a direct effect on whether it is sievable or not, whether it is winnowable by wind or by shaking, and so on. Similarly, the size and the weight have direct affect on where and how the weeds are processed.

The final observation relates to the distribution of components between sieve sizes. In general, the higher the processing stage (closer to the consumption product) the fewer sieve A components in the crop products and byproducts. In the last few stages, such as winnowing by shaking 1, winnowing by shaking 2, pounding and winnowing by shaking 3, however the crop products and byproducts have only sieve B and sieve C components, the majority being in the sieve C. Sorghum bicolor seeds are never in sieve A and are always in sieve B and sieve C. This pattern is expected since the bigger the size of non-crop grain components (sieve A sized components), the higher the chances of them being processed out. They are simply more visible and therefore easier to hand sort out and also easier to winnow out through wind (especially straw). The use of the sieve at a relatively early processing stage further facilitates the separation of the bigger sized material.

Pennisetum typhoides

Pennisetum typhoides is an annual grass, with a solid erect stem which bears the compact inflorescence at the tip (Figure 5-4). The plant tillers profusely producing a leafy growth. The unbranched inflorescence has a straight rachis which bears the spikelets on an involucre and rachillas. These spikelets bear the seeds which are caryopsis. The rachis is unbranched, solid and straight, tapering gradually from base to apex. The Pennisetum typhoides caryopsis do not have a clasping palea and lemma

similar to free threshing wheats. Therefore they thresh free without much effort on the part of the processor, although there are the occasional ones which do not get freed. During the composition analysis the major components isolated in the Pennisetum typhoides samples are: straw, husk, Pennisetum typhoides rachii with rachillas bearing spikelets, Pennisetum typhoides rachii without rachillas, Pennisetum typhoides rachillas without seeds, Pennisetum typhoides rachillas with seeds, Pennisetum typhoides seeds, Pennisetum typhoides seeds with husk, and a range of weed species (Figure 5-4).

General Patterns

Some initial general observations can be made of the Pennisetum typhoides samples. First, some differences were observed between the three Pennisetum typhoides plots that were studied. The main differences lie in frequencies of the rachillas without spikelets, and the ranges and frequencies of weed categories. Pennisetum typhoides plot 3 has a significantly higher frequency of rachillas without spikelets, while the Pennisetum typhoides plots 1 and 2 have lower and comparable frequencies of this component. This pattern is probable due to the locations of the three plots; plots 1 and 2 were relatively close to a water channel, while Pennisetum typhoides plot 3 was much further from a water channel. Having relatively less water available for the plot 3 plants dried the plants well before harvest and threshing. Thus, it is easier for the spikelets and grain of drier Pennisetum typhoides panicle heads to dislodge from the rachillas. This resulted in the higher frequencies of rachillas without spikelets in plot 3.

Overall, there were fewer weeds in Pennisetum typhoides plot 3 as compared to plots 1 and 2. Plot 1 has the highest frequency of weeds but it is also very disturbed in terms of it being the closest to a pathway, and also to a field of a different crop (field

weeds are most often associated with disturbed areas). These factors could have an effect on the numbers of weeds. It is important to note however that plot proximity to a water channel could be a causal factor in this patterning. Both plots 1 and 2 have water channels in relatively close proximity as compared to plot 3 (see Figure 4-4). Therefore it is possible that plot 3 has a lower frequency of weeds because it was getting less water and was drier, while plots 1 and 2 have a higher frequency of weeds because they were close to disturbance areas (pathway and other crops). The differences could also be due to sample size and variability, and not related to these other ecological factors.

The processing pathway of Pennisetum typhoides is a complex nonlinear procedure where decision making on the part of the processor plays an important role (Figure 5-5). This decision making is based on experience and other factors such as amount of material being processed, economic needs and cultural values. For example deciding when a winnowing byproduct has significant amount of crop grain that it cannot be discarded, instead a separate processing sub-pathway should be initiated to extract these grain. This decision making is not quantifiable, but is a very important aspect of the processing.

A second observation regarding Pennisetum typhoides processing relates to how weeds fall out in the processing pathway. Weeds occur in higher frequencies in the assemblages of the later processing stage products and byproducts (as compared to the earlier ones). Essentially, they are actively processed out in the later stages in significant frequencies. This differs quite distinctly from Sorghum bicolor processing where weed frequencies decrease significantly through the processing pathway. One reason for these differences could relate to the different sizes of the two crop grains, particularly in relation to the weed seed sizes, even though both Sorghum bicolor and Pennisetum typhoides are Type A crops. The Sorghum bicolor seed is much bigger than the Pennisetum typhoides seed. Therefore the size of the Pennisetum typhoides crop

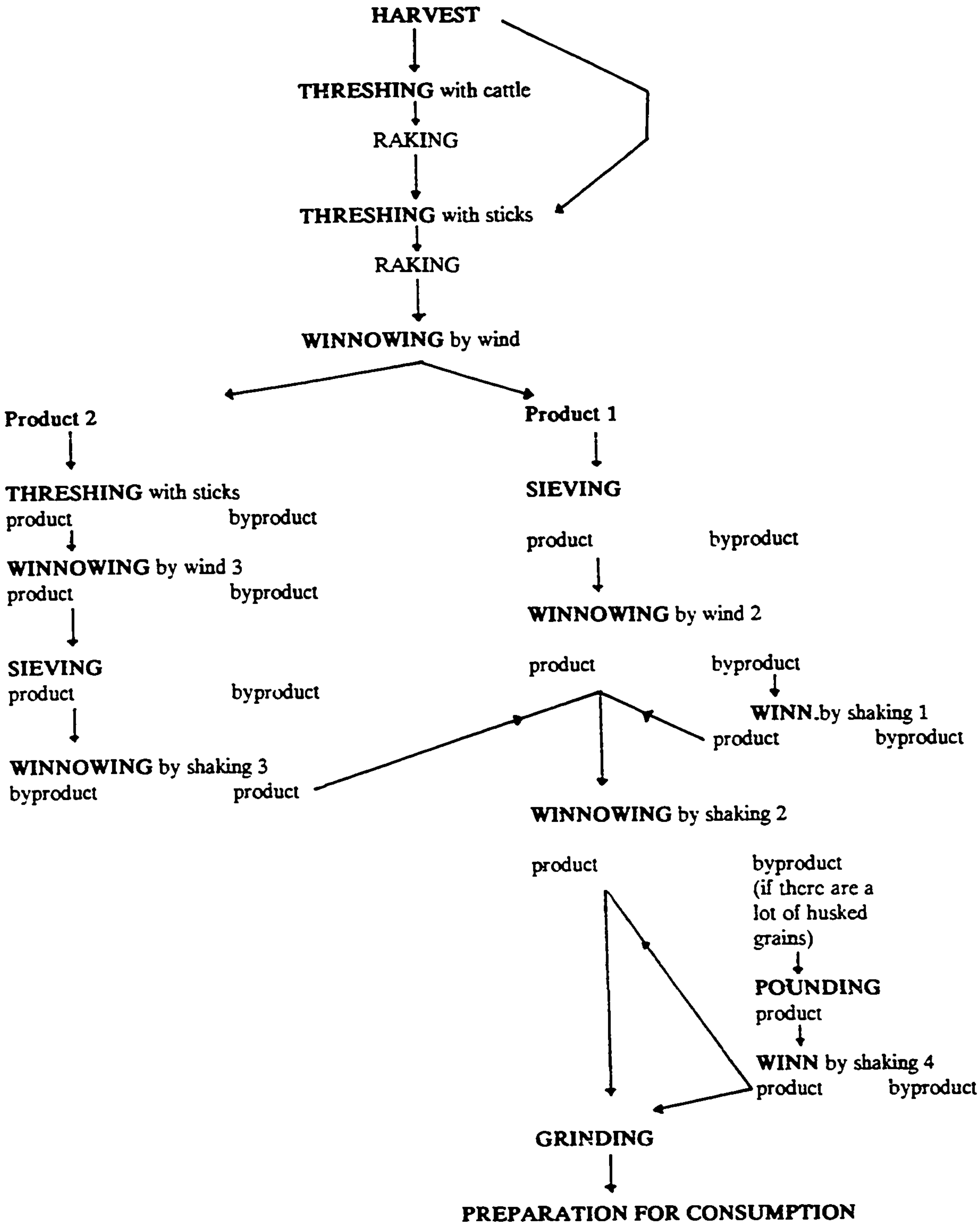


Figure 5-5. Pennisetum typhoides Pathway

grain is effecting the removal of other seeds (weeds) in the initial stages since the focus of these initial processing activities is to separate the larger non-crop grain components such as straw, rachii and rachillas. In the later stages when the focus is more on the smaller sized components, the weeds are processed. Therefore, the smaller the prime grain the greater the number of weeds in the later processing stages. Furthermore, in general there is purposeful concentration on processing out larger sized non-crop grain components in the earlier stages; therefore if an assemblage (archaeological or ethnographic) has mostly crop grain, smaller non-grain crop components and weeds, it is most likely closely related to a later processing stage product than an earlier stage such as winnowing by wind or sieving.

Another observation related to the patterning of the weeds is that there is a significant loss/elimination of tail grain in later stages such as winnowing by wind 2 byproduct, and winnowing by shaking byproduct. There is relatively little loss of Pennisetum typhoides grain (tail and prime) in the initial stage byproducts. This changes dramatically in the later stages when there is a conscious attempt on the part of the processor to eliminate the tail grains.

Lastly, similar to Sorghum bicolor, Pennisetum typhoides grains with husk occur in relatively high percentages throughout the processing stages. I propose that this patterning reveals that processing is not a simple elimination activity where there is singular selection for Pennisetum typhoides prime grains without husk, but rather is an involved process where there is a conscious effort to maximize the retrieval of Pennisetum typhoides seeds both with and without husk.

Detailed Analysis

After sorting and categorization, the data analysis involved identification of patterns that related to the different processing activities and isolation of variables that

are indicative of particular processing activities.

Standardization was the first step of the data analysis. As mentioned previously, this was done using standardized weights to make the data from Pennisetum typhoides samples comparable to the Sorghum bicolor and Panicum miliare data. The standardized data was then used for pattern searching and analysis (Table 5-2).

For the pattern searching and isolation of variables that distinguish processing stages products and by products, the standardized data from the three plots of Pennisetum typhoides were averaged. This was done to create a more representative sample encompassing the range of ecological variables identified in the field. The results of the analysis and pattern searching of crop components are examined in the following order: straw, rachii without rachillas, rachii with rachillas, rachillas without spikelets, rachillas with spikelets, Pennisetum typhoides grain with husk, dehusked Pennisetum typhoides grain, and a range of weeds.

Straw

The straw component is present in significant amounts mainly in the initial stages of processing, and when present in the later stages it occurs only in sieve C. Straw is present in relative significant amounts in the threshing products, winnowing by wind product and byproduct, and sieving byproduct (Table 5-2). In winnowing by wind 2 byproduct, it is present only in sieve C. These stages are also characterized by high frequencies of by rachii, both with and without rachillas. These two components, straw and rachii, are distinguishing variables for these stages, but they cannot be used as strong isolating variables for archaeological modeling since their preservation, survival and discovery is unlikely. This is due to their characteristics and nature, the processing stage locations, and this differs from other components. Straw is processed out most

Table 5-2. Standardized Data of Pennisetum typhoides Plots Combined

	ThProd.1	ThProd.2	Win(w)Prt.	Win(w)Byp	Siev.Prdt	Siev.Byp	Win(w)3 Prd	Win(w)3 Byp	Win(s) Byp
Straw/Chaff (ml)	357	2345	16	16412		1112			
Rachilla w/o seeds	28348	173340	806	661407	14	31715		666	129
Rachilla w/seeds	2747	1624	2349	465	15	34711		366	43
Rachii w/o rachillas		98	2	11		85			
Rachii w/rachillas	7	146	4	162		182			
Husk (no.)	2680	26	11	20919	85	376	19	162	378
Penn.grainw/husk (spks)	2019	826	1787	624	1551	5541	971	6036	3974
Penn Grain	62269	54227	47873	829	50861	27521	54040	74594	81049
Weeds (#)	2317	2923	2606	4617	1791	1767	5379	51277	11094
Pesi (BFH)					1	4			
Amaranthus sps (SFH)	729	475	860	573	470	28	1553	15841	1671
Carvia spk (SHH)	1	17		69		3			9
Carvia sps (SHH)	6	12	3	18	8	5	20	31	56
Chloris sps (BHL)	0	1		11					19
Dactyloctenium sps (SFL)	531	1014	790	404	624	45	1085	23815	4265
Datyloctenium spks (SHL)	98	661	123	1724	1	712	13	40	870
Digera sps (SFH)	226	122	107	247	124	588	520	1961	321
Digiteria sps (SFH)	8		9	15	5		33	21	54
Eragastis spk (SHL)	6	25	2	138		42			9
Eragastis sps (SFL)	109	30	134	65	91	9	544	2905	800
Eremopogon spk (SHL)		1		13		28			
Eremopogon sps (SHL)		225	2			6		1528	
Erythrina sps (BHH)									7
Fesculus (BHH)			1						
Hylandia sps (SFH)			1			8	2		
Indigofera sps (SFH)	3		7	18	1	9	7		6
Iseilema sps (SHL)	1	8	2	33		16	3		47
Lannea sps (BFH)						4			
Lepidium sps (SFH)	15	27	17		12		2	381	41
Leptochloa sps (SFH)		1	1		2			167	3
Medicago (sps) SFH)		1	1		1				
Oxysteima sps (BFL)		4				2			
Paspalum sps (SHH)			53		20				
Phyllanthus sps (SHH)	25	7	46	15	21	7	87	558	96
Physalis sps (SFH)	2		1		2			167	3
Setaria tomentosa (SHH)	341	61	254	179	232	8	1070	2359	1576
Sida sps (BHH)					1	9			
Trianthema sps (SFH)	162	96	175	167	166	13	358	1409	1020
Trianthema w/rachus (SHH)	3		2		5		48	55	25
Triumfetta sps (BHH)	1	1	2			30	2		19
Vernonia sps (BFL)	50	134	13	928	4	191	32	39	177
Total SFH Weeds	1145	722	1179	1020	783	646	2475	19947	3119
Total SHH Weeds	376	97	358	281	286	23	1225	3003	1762
Total SFL Weeds	640	1044	924	469	715	54	1629	26720	5065
Total SHL Weeds	105	920	129	1908	1	804	16	1568	926
Total BFL Weeds	50	138	13	928	4	193	32	39	177
Total BHH Weeds	1	1	3		1	39	2		26
Total BHL Weeds		1		11					19
Total BFH Weeds					1	8			

Key

Threshing Product 1	= ThProd.1	SFH = Small Free Heavy
Threshing Product 2	= ThProd.2	SHH = Small Headed Heavy
Winnowing (w) Product	= Win(w)Prt	SFL = Small Free Light
Winnowing (w) Byproduct	= Win(w)Byp	SHL = Small Headed Light
Sieving Product	= Siev.Prdt	BFL = Big Free Light
Sieving Byproduct	= Siev.Byp	BHH = Big Headed Heavy
Winnowing (w) 3 Product	= Win(w)3Prdt	BHL = Big Headed Light
Winnowing (w) 3 Byproduct	= Win(w)3Byp	BFH = Big Free Heavy
Winnowing (s) Byproduct	= Win(s)Byp	

efficiently in the sieving that follows winnowing by wind. The characteristic pattern of straw mentioned previously is that the higher the stage the lesser the amount of straw, and straw occurs predominantly in the smaller sieve C. This pattern supports the assumption that the processor and the processing activities first select out the larger material in the earlier stages and the smaller materials are selected out in the later stages.

Rachii

Analysis of the distribution of Pennisetum typhoides rachii without rachillas reveals that they are most prevalent in sieving byproduct, followed by the winnowing by wind byproduct and product (Table 5-2). Most are processed by sieving which is later than winnowing where there is some processing out of the rachii without rachillas. Similarly, rachii with rachillas are most dominant in the sieving byproduct, followed by winnowing by wind byproduct and product. Thus, both rachii without rachillas and rachii with rachillas are partially processed out in the winnowing by wind and then intensively processed in sieving. This pattern in expected since the rachii (with or without rachillas) are heavy enough not to be processed out fully by winnowing by wind, but are large enough to be sieved out in the ethnographic sieving. These are large components relative to the prime grain, and are processed out in the earlier stages, and their presence archaeologically can be used as a distinctive indication of an earlier stage of processing.

Rachillas without spikelets

The next component, rachillas without spikelets, is most dominant in the first winnowing by wind byproduct (Table 5-2). This component also is present to some degree, even if in relatively negligible percentages, in all the stages studied. The

relative frequency of the component decreases with each processing stage, and the majority are processed out through winnowing by wind. Their presence is strong in the threshing products and moderate in sieving byproduct, but in rest of the stages product and byproducts they occur in very low percentages. Therefore, when rachillas without spikelets dominate an assemblage, the assemblage can be considered as being closely related to a winnowing by wind byproduct.

Rachillas with spikelets

Rachilla with spikelets also occur in all stages products and byproducts (Table 5-2). However, they are most frequent in sieving byproduct, and occur in very low percentages elsewhere. In sieving byproduct, they occur moderately and in similar frequency to rachillas without spikelets. Although they do not dominate the sieving byproduct, when an assemblage has moderate numbers of rachillas with spikelets, along with moderate numbers of rachillas without spikelets, then the assemblage can be correlated with a sieving byproduct. Rachillas with spikelets, however, are not as strongly associated with one stage as are the rachillas without spikelets.

Pennisetum typhoides grain with husk

This component occurs in all the products and byproducts in varying frequencies, but is most dominant in winnowing by wind 2 byproduct and sieving byproduct (Table 5-2). Its presence throughout the stages, reveals that there is no purposeful selection against this component, and that the Pennisetum typhoides grain with husk are desirable grain. Their relatively high frequencies in winnowing by wind 2 byproduct and the sieving byproduct does not contradict this assertion, since the grains with husk which occur in these two byproducts have distinct set of characteristics that

make them undesirable grain. A significant percentage of the Pennisetum typhoides grain with husk in the winnowing by wind 2 byproduct are tail grains recovered from sieve C (prime grains are predominantly in sieve B). The grains in sieving byproduct are predominantly the fungal infected grains which causes them to become enlarged and sieved out. Tail grains are selected out purposefully since they effect the final quality of the crop grain. Concurrently, it is evident that the processor is making a conscious attempt not to remove the Pennisetum typhoides grains with husk, instead to invest in dehusking them at a later stage (but before the grains are pounded or ground into flour). Depending on the frequency of grains with husk, they can be separated from the grains without husk, pounded to dehusk them, and then combined back to grind them all together into flour.

Pennisetum typhoides grains without husk

The grains without husk are the prime grain and the most desirable component. They are present in varying frequencies in all the stages crop products and byproducts. They dominate the assemblages of winnowing by wind product, sieving product, winnowing by wind 2 product and winnowing by shaking byproduct. They occur in relatively strong proportions in the threshing products and winnowing by wind 2 byproduct. The byproducts of sieving and winnowing by wind have moderate to low amounts. It is expected that the products of the different stages have Pennisetum typhoides grain without husk in dominant frequencies (the presence of grain in winnowing by shaking byproduct, however, needs further explanation). Sieve size distribution is of crucial importance in understanding the distribution of grain in products versus byproducts. Winnowing by shaking byproduct has Pennisetum typhoides grain without husk in dominant frequencies, but they are mostly of sieve C size (therefore they are interpreted as tail grain). In contrast, the various stage products

have predominantly sieve B grain, with the sieve C grains decreasing as the stage product is higher in the processing pathway (in other words closer to the consumption product). Thus, the size of the Pennisetum typhoides grains plays an important role in determining when an assemblage is a byproduct versus a product. Additionally, the tail grain are processed out predominantly in the later winnowings, since the Pennisetum typhoides grain without husk sieve C occur in high frequencies mainly in the winnowing by wind 2 and winnowing by shaking byproducts. This pattern again demonstrates the concentration on the part of the processor during of the earlier processing stages on the elimination of larger non-crop grain components, while in the later stages the focus moves to the smaller undesirable components. This pattern has important implications for archaeological modeling, since the probability of the later stages products and byproducts surviving and being discovered is much higher, as compared to the earlier stages, since the later processing stages occur almost predominantly in domestic locales.

Weeds

Weeds in Pennisetum typhoides plots are present in relatively high frequencies in all the stage products and byproducts studied (Table 5-2). All the weed categories are represented and consist of small headed heavy (SHH), small free heavy (SFH), small free light (SFL), small headed light (SHL), big headed heavy (BHH), big free heavy (BFH), big headed light (BHL), and big free light (BFL). The small free heavy weeds are the most ubiquitous, followed by small headed light (SHL), small headed heavy (SHH), and small free light (SFL). Not only do the small free heavy (SFH) weeds occur in the highest frequencies overall, and they are also dominant in most stage products and byproducts. They occur in higher frequencies in the various products, and

do not get processed out till the later stages, particularly winnowing by wind 2 byproduct onward. In general the four big sized weed categories occur in lower frequencies as compared to the smaller sized categories. Among the big sized weeds, the big headed heavy and big free heavy are the most frequent. The ratio of headed to free weeds is 1: 1.3, meaning there is slightly higher incidence of the free characteristic weeds in the processing pathway than the headed weeds. The critical question, however, is where they are processed out from the crop products within the pathway.

The patterning of the weed categories down the processing pathway is intricate in that the different categories occur in varying frequencies at different stages. Small headed heavy (SHH), small free heavy (SFH), small free light (SFL) weeds, however, are processed out essentially by winnowing by wind 2, although they are also processed out minimally in the earlier stages. The small headed light (SHL), big headed heavy (BHH), big free heavy (BFH) and big free light (BFL) weeds are processed out by sieving. The big headed light (BHL) weeds are processed out mostly by the first winnowing by wind. Thus, different weed categories occur at differing levels of significance in the different processing stages. Therefore, they can used as indicators of these processing stages crop products and byproducts. Nonetheless, the weed categories alone cannot be used as isolating variables, but a combination of the ratios of specific weeds to at least one or more other components (such as crop grains with or without husk, rachii, rachillas), can be successfully used to identify assemblages relating to the crop products and byproducts of different processing stages.

Summary of Pennisetum typhoides

In summary, several key observations can be made about the patterning of various components in the products and byproducts from the different crop processing stages of Pennisetum typhoides.

Pennisetum typhoides rachii with and without rachillas are clear indicators of lower processing stages such as threshing, winnowing by wind and sieving (Table 5-2). They are predominantly processed out through sieving. However, they have limited utility for use as exclusive isolating variables for archaeological contexts, since they are not likely to survive into the archaeological record. For archaeological contexts, the preservation of these rachii and their discovery is mainly dependent on whether they became carbonized. As in the case of Sorghum bicolor, there are two main factors which determine whether this component is an archaeologically strong isolating variable: the location of the processing and the likelihood of the component being exposed to fire. Threshing and the initial winnowing by wind most often occur in the fields, and thus are less likely to be discovered archaeologically, and their exposure to fire is minimal. Therefore, although the rachii are good indicators of sieving, winnowing by wind and threshing, they do not have a high index of significance as isolating variables.

Rachillas without spikelets can be used as a isolating variable for winnowing by wind byproduct, since they dominate these assemblages (see Talbe 5-2). They are being processed out predominantly through winnowing by wind, and thus occur in high frequencies in the byproducts of this stage. In contrast, the rachillas with spikelets are not a very discriminating component. However, they do occur in the highest frequencies in the sieving byproduct. Thus if an assemblage is dominated by rachillas without spikelets, then the assemblage is most closely related to winnowing by wind byproduct. On the other hand, if an assemblage has both types of rachillas occurring in moderate amounts it is most closely related to a sieving byproduct. However, such correlations are accurate only when more than one component is used to characterize the assemblages.

Pennisetum typhoides grains with and without husk are important indicators for crop products from all stages, as opposed to crop byproducts (Table 5-2). The key element of this pattern entails the size of the crop grains. The prime grain are predominantly in sieve B, while the tail grain (including the immature grains) are in sieve C. The distinction of Pennisetum typhoides grains associated with crop products versus those associated with crop byproducts lies in the sieve size of the respective grains. Those crop byproducts that have crop grains in dominant frequencies, have predominantly sieve C grains, while the crop products, particularly in the later stages, have more sieve B grains. Therefore, grain size measurements are critical in determining the nature of an assemblage dominated by Pennisetum typhoides grains.

In sum, the presence or absence of Pennisetum typhoides grains solely cannot be used alone to determine a particular processing stage, but their distribution must be used in conjunction with other components. For example, if the Pennisetum typhoides seeds with and without husk constitute the majority of the assemblage, then the assemblage could be interpreted to be comparable to a winnowing by wind 2 product, or a sieving product. This reiterates a key point- individual components cannot be used as the singular isolating variables or indicators.

Weed categories are important distinguishing variables, and in conjunction with other components they provide distinct signatures to differentiate various stages products and byproducts. One distinctive pattern of the weed categories distribution along the processing pathway is that the majority of the weeds are processed out in the later stages, since the focus of the earlier processing stages is on the larger non-crop grain components. This is important for archaeological modeling, since the later stages products and byproducts are more likely to be discovered archaeologically.

Typically, the higher/later the processing stage the smaller the size of the components: there are negligible amounts of sieve A components, and in the last few

stages there are only sieve B and C components. Pennisetum typhoides grain occur mostly in sieve B and C, and when they occasionally occur in sieve A, they are usually the infected bloated grains. This pattern also occurs with Sorghum bicolor and is an expected pattern, since the bigger the size of non-crop grain components (that is sieve A components) the higher the chances of them being processed out early. The larger the component, the higher its visibility, and therefore the more likely it is to be hand sorted out. In addition, the ethnographic sieving (a relatively early processing stage) also serves to sort out large undesirable components. In relation to this size discrimination along the pathway, the Pennisetum typhoides processing study reveals that weeds (which are typically small) are primarily processed out in the later stages. This is a key pattern for archaeological modeling, since the assemblages from these later stages are typically recovered archaeologically.

An Ethnographic Model for the Processing of Type A Crops (Sorghum bicolor and Pennisetum typhoides)

As discussed in chapter 4, Sorghum bicolor and Pennisetum typhoides can be harvested in three different methods: (1) a typical type I harvest method, (2) a typical harvest B method and (3) an intermediate method similar to type II harvest (see glossary). The difference in the three harvesting methods has considerable effect on the compositions of the crop products and byproducts at the various processing stages. Of the three methods, the type II method of harvest of Sorghum bicolor and Pennisetum typhoides was studied in this project. This is most representative of all the three methods and by addressing this method the research takes into consideration all possible variations in the crop product and byproduct compositions at different stages due to the methods of harvests. Therefore, the model developed for Sorghum bicolor and

Pennisetum typhoides is for when they are harvested in a type II method (Figures 5-6 and 5-7). However, the patterning of the components for the other two methods of harvests are within this same model, since it is mostly a matter of the inclusion or not of certain crop components. For example if the type A crop was harvested in a type I method, then only the panicle heads would be included into the processing pathway. Therefore the components of the different products and byproducts would be restricted only to the crop rachii, rachillas, spikelets and grains. Variations in the model when the two crops are harvested in type I method will be discussed later.

The patterns distinguished in data analysis and discussed in detail previously are summarized in table 5-3 for Sorghum bicolor and table 5-4 for Pennisetum typhoides. These patterns provide the framework for building ethnographic models for the processing of Type A crops growing with weeds harvested in a type II method. Table 5-3 combines the data from both the Sorghum bicolor plots (S1 and S2) while the data from all the three Pennisetum typhoides plots (P1, P2, P3) are combined in table 5-4. The distributions for each component were collapsed into 6 ranges which were given qualitative terms, ranges and symbols (see respective tables for details); absent O, extremely rare -o, rare -, moderate x, strong xx and dominant xxx. The resulting tables are the consolidation and expression of these classifications, and provide the framework to understand the crop processing of Type A crops, such as Sorghum bicolor and Pennisetum typhoides growing with weeds, when they are processed through the following stages: threshing with cattle, threshing with sticks, winnowing by wind, sieving, winnowing by shaking, pounding and grinding.

In addition to distribution patterns of crop grain and non-grain components down the processing pathway, there are four independent factors that are instrumental in accessing the probability of the different components entering the archaeological contexts. They are: likely to be prone to accidental or intentional fires (high likelihood

Table 5-3. Tabulation of Sorghum bicolor pattern of distribution

STAGES	Straw	Panicles	Rachillae	Sorghum grain w/husk (spks)	Sorghum grain w/out husk	Total weeds	SHH	SHL	SFH	SFL	BHH	BHL	BFL
Th Prd	x	--o	--	x	x	xxx	-o	--	xx	xxx	-o	-o	-o
Win(w) Prd	--o	--o	x	xx	xx	xx	-o	-o	xxx	xx	o	o	-o
Win(w) Byp1	xxx	--	--	--	--o	x	--	xx	x	x	o	--	--
Win(w) Byp2	xxx	--o	--	o	o	x	--	xx	xx	x	o	--	--
Siev Prd	--o	o	o	x	x	xxx	-o	-o	xxx	xx	o	o	-o
Siev Byp	--	--o	xxx	o	--	--	-o	xx	xx	x	o	-o	x
Win(s) Prd	o	o	o	xxx	xx	--	xx	o	xx	x	o	o	o
Win(s) Byp	--	o	o	xx	--	xxx	-o	-o	xx	xxx	o	o	-o

o = Absent (0%)
—o = Extremely rare (0-1%)
-- = Rare (1-7%)
x = Moderate (8-20%)
xx = Strong (21-50%)
xxx = Dominant (51-100%)

SHH (small headed heavy)
SHL (small headed light)
SFH (small free heavy)
SFL (small free light)
BHH (big headed heavy)
BHL (big headed light)
BFL (big free light)

Table 5-4. Tabulation of Pennisetum typhoides pattern of distribution

STAGES	Straw	Rachil w/ rachillae	Rachillae w/out rachillae	Rachillae w/ seeds	Rachillae w/o seeds	Husk	Penn. spikelets	Penn. grain	Total Weeds	SHH	SFH	SFL	SHL	BHH	BFH	BHL	BFL
Th Prd 1	–o	–o	o	–	x	–	–	xx	–	–o	–	–o	–o	–o	o	o	–o
Th Prd 2	–	–o	–o	–o	xx	–o	–o	x	–	–o	–o	–o	–o	–o	o	–o	–o
Win(w) Prd	–o	–o	–o	–	–o	–o	–o	xxx	–	–o	–	–	–o	–o	o	o	–o
Win(w) Byp	–o	–o	–o	–o	xxx	–	–o	–o	–o	–o	–o	–o	–o	o	o	–o	–o
Siev Prd	o	o	o	–o	–o	–o	–	xxx	–	–o	–	–o	–o	–o	–o	o	–o
Siev Byp	–o	–o	–o	x	x	–o	–	x	–	–o	–o	–o	–o	–o	–o	o	–o
Win(W) 2 Prd	o	o	o	–o	–o	–o	–	xxx	–	–o	–	–o	–o	o	o	o	o
Win(w) 2 ByP	–o	o	o	–o	–o	–o	–	xx	x	–o	x	–	–o	o	o	o	–o
Win(s) ByP	o	o	o	–o	–o	–o	–	xxx	–	–o	–	–	o	–o	o	o	o

o = Absent (0%)
–o = Extremely rare (0-1%)
– = Rare (2-15%)
x = Moderate (16-45%)
xx = Strong (46-70%)
xxx = Dominant (71-100%)

SHH (small headed heavy)
SHL (small headed light)
SFH (small free heavy)
SFL (small free light)
BHH (big headed heavy)
BHL (big headed light)
BFH (big free heavy)
BFL (big free light)

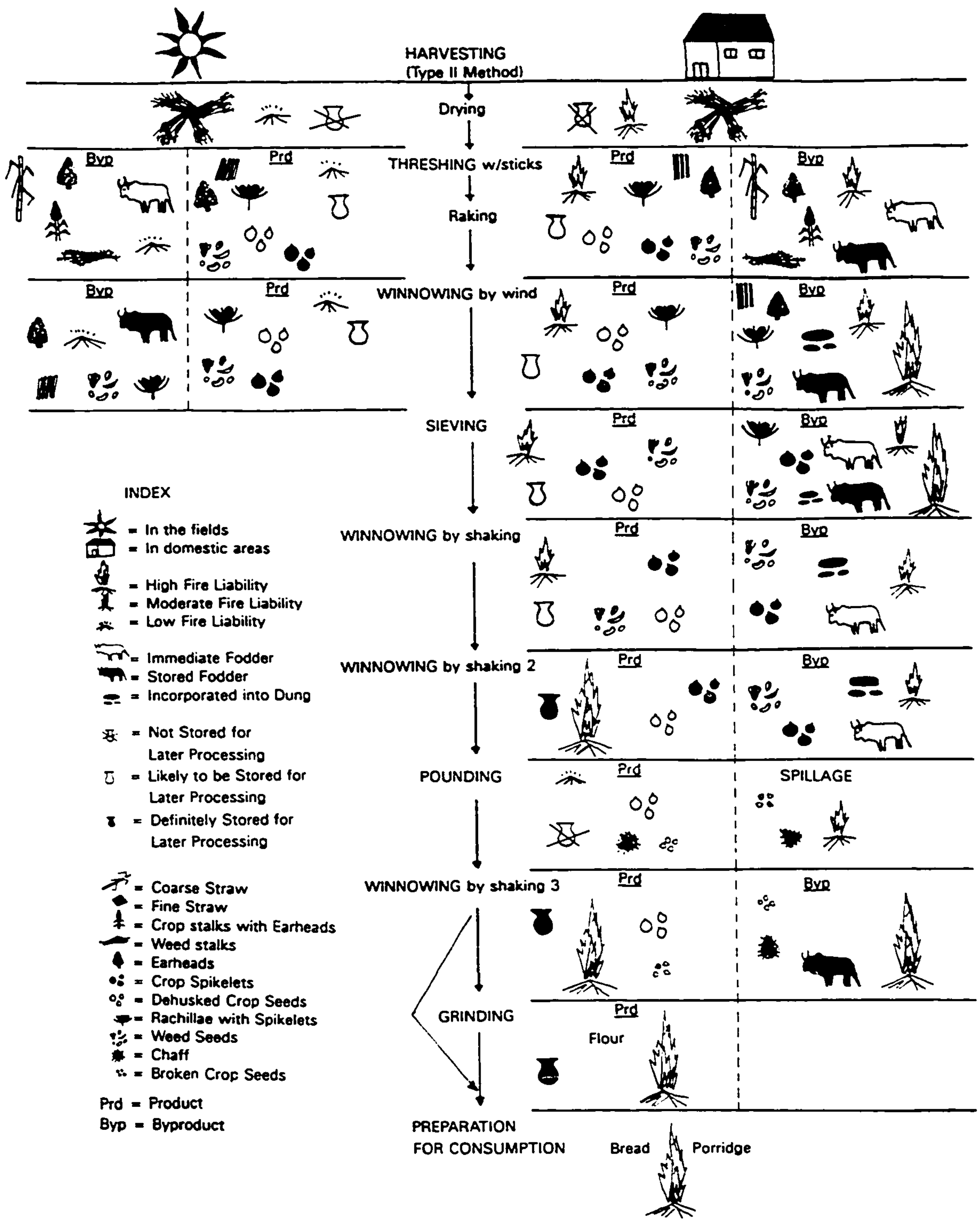


Figure 5-6. Model for <u>Sorghum bicolor</u> Processing

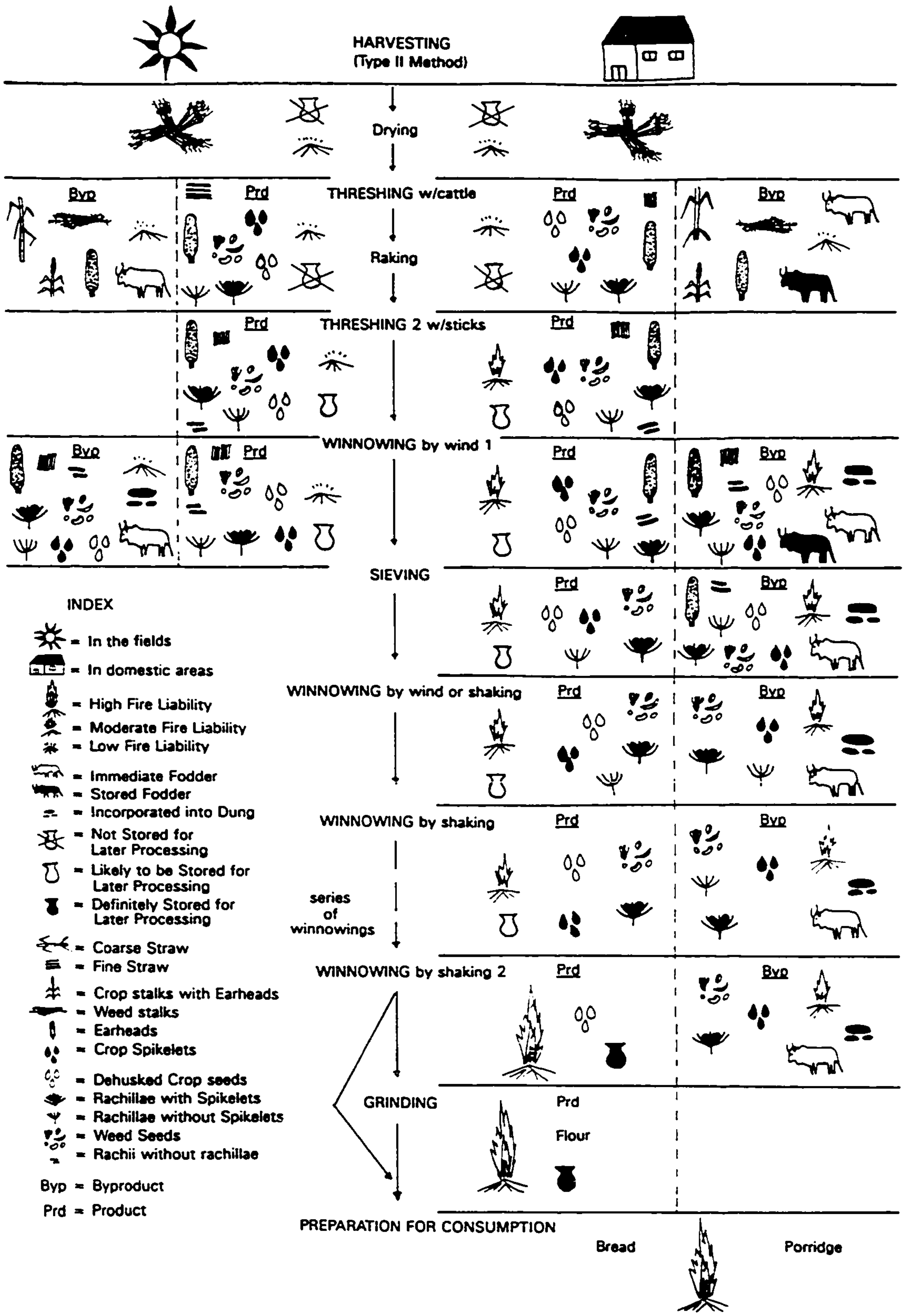


Figure 5-7. Model for Pennisetum typhoides Processing

to low likelihood), storage of crop product (unlikely to definitely), fodder use (immediate or stored), and incorporation into dung as temper or fodder and subsequent use as fuel. All the products and byproducts from the processing stages are ranked for each factor. The ranking is not subjective, it is based on ethnographic observations, archaeological data, and post depositional studies.

The ranking according to their liability of being in accidental burning/fires is critical because this allows for the investigator to recognize which asemblages are most important for archaeological situations. The degree of exposure of a crop product or byproduct to fire, is ranked into three levels: high liability (F1), moderate liability (F2) and low liability (F3). If an assemblage has a high index of being accidentally burned, then it has a higher chance at surviving into the archaeological record. It is important to note, however, that there are some components from assemblages (such as straw) which have a moderate likelihood of being burnt but a very low chance at surviving into the archaeological record or being discovered archaeologically. Such a component though potentially significant, is not a critical isolating variable. The fire exposure index of a crop product or byproduct is based on several factors including location of processing, storage index, and the characteristics of the processing stage itself. An assemblage that is definitely stored in domestic areas has a higher chance of being exposed to accidental and catastrophic fire. In addition, the later stages are most often done in close proximity to cooking areas and this also increases fire exposure. Thus, the last winnowing by shaking products have a high fire exposure index since the processing of winnowing by shaking before grinding often occurs in the front/back yards near cooking areas, and the byproducts are often swept into the hearths (Figure 5-6, Figure 5-7).

The next important factor in accessing the probability of the different components entering the archaeological context is crop storage. Crop storage categories

include not stored for later processing (NSLP), likely to be stored for later processing (LSLP) and definitely stored for later processing (DSLP). A crop product that is definitely stored for later processing has a higher probability of entering the archaeological record (this is also, of course, dependent on the fire liability index), while a crop product that is not stored for later processing has a low to negligible probability. In general, crop products which are closer to consumption have a lower probability of being stored for later processing, however crop products that are ready for consumption also have a high storage likelihood. This storage (of crop products that are ready for consumption) is significantly different than the storage index being discussed here, since the storage of the crop products which are ready for consumption are totally clean while the other crop products are not cleaned and have non-crop grain components.

Whether a crop product is stored for later processing is dependent on the next stage of processing, nature of the material, and other demands on the farmer. For example, crop products are typically not stored for long periods after they are pounded, since the grain has to be separated from the chaff dust through winnowing by shaking. Damage through fungal/bacterial infection to crop products may occur if they are stored in such conditions (after pounding but before winnowing by shaking). Thus, the storage factor is also dependent on whether the crop product can survive storage without being subject to fungal, bacterial infection, and prey to small animals such as rodents.

In general, Sorghum bicolor and Pennisetum typhoides do not store well over long periods of time. This is due to their dehulled nature (naked grains without a pericarp) and hence they run a relatively high risk of damage through insects or fungus during storage. A survey of storage rates in a non-urban context in India revealed that in most households damage to stored Sorghum bicolor and Pennisetum typhoides was

between 90-93%, while in dramatic contrast storage damage to Panicum miliare and Setaria italica was 2-3% (Pushpamma 1989). Additionally, storage of crops like Sorghum bicolor was significantly lower on average when compared to crops such as Panicum miliare and Setaria italica.

For Pennisetum typhoides, rodents are serious pests which limit production and storage. Pennisetum typhoides grain storage is often inadequate, since it is susceptible to storage pests, molds and rodents. Thus it is important to note that there are diseases of serious consequence to the Pennisetums. However, the relatively short growth cycle of the crop and its cultivation in dry regions, often directly following a long, hot, dry season (as is the case in Gujarat), may tend to reduce the incidence of serious limiting pathogens. Recent hybrids in general are more susceptible to pests and pathogens than the traditional non-hybrids. Loss of Pennisetum typhoides grain during storage from rodents alone is estimated to be 25% in India (Rachie and Majmudar 1980). According to Rachie and Majmudar (1980) Pennisetum typhoides grain storage in India occurs soon after threshing of a well dried crop (the drying before threshing ranging from few days to several weeks, depending on weather and other conditions). In addition, good quality Pennisetum typhoides heads are sometimes stored for future sowing. Storage is in jute/cloth bags, earthenware, metal or woven basketlike containers or in pits lined with straw. (It is important to note that Pennisetum typhoides grain storage in Africa involves storage of the crop on the head, while in India loose grain is typically stored).

Rachie and Majmudar's (1980) study, however, only deals with larger farms, and it is important to note that storage patterns vary depending on the size of the farm. Typically the smaller farmers tend to process (clean) the crop into the later processing stages in the immediate weeks following the harvest, while the larger farms tend to store immediately after threshing and before any cleaning. The large farms then market the grain to grain merchants in this condition, while the smaller farms tend to market

cleaner crop products. This has significant implications for archaeological interpretations and modeling. For this study, the small farm procedures are used for archaeological modeling of the Late Harappan in Gujarat, since they are more applicable than the larger farm techniques of modern India.

Use of a crop product or byproduct as fodder is an issue of considerable importance since it relates directly to one of the main themes of this project; the use of millet crops as fodder for animals in the Late Harappan of Gujarat. Determining whether the crop product or byproduct is used as immediate fodder or as stored fodder is just as important as the question of whether a crop product or byproduct is used as fodder. The index of fodder popularity (with respect to terms of immediate fodder use or stored fodder) helps elucidate the selection of certain products/byproducts for animal feed. Selection for specific stage byproducts (or in rare cases, products), indicates that the selection is based on certain requirements or needs of the animal (for example, fresh fodder is better for lactating animals). Specific selection of a crop byproduct for fodder, and storage of this byproduct for later use as fodder demonstrates the importance of this plant material. Certain crop products may have a high fodder popularity but low storage possibility due to the nature of the plants (i.e. does not store well for long periods). When an assemblage (crop product or byproduct) is used as immediate fodder then the likelihood of this assemblage entering the archaeological record as a distinct collection is minimized. In contrast, when an assemblage is stored for later use as fodder this increases the chances of entering the archaeological record. Of course, this is subsequently dependent on whether the assemblage is carbonized through exposure to fire, and the context in which this occurs (archaeologically discoverable location or not). Whether an assemblage (crop product or byproduct) is stored or used as immediate fodder is dependent on several factors some of which are

measurable. These include: nature of the assemblage (fresh or dry), amount of the assemblage (plenty or little), location of the processing activity (in the fields or in domiciles), and lastly the presence or not of animals within the household.

When the Sorghum bicolor and Pennisetum typhoides plants are relatively fresh (green) at the time of harvest and are not well dried, then crop byproducts such as the stalks and straw are not stored for later use as fodder (Figures 5-6, 5-7). Instead they are given as immediate fodder. The storage of wet, green Sorghum bicolor and Pennisetum typhoides plants runs the risk of a fungal infection on the vegetative parts of the plant which on ingestion by cattle can cause often fatal stomach bloat. Therefore in majority of the cases, fresh Sorghum bicolor harvests result in the crop byproducts being fed as immediate fodder to animals. This is of significance in places like Africa where the harvest of these millets occurs during the wetter months (Rachie and Majmudar 1980). In contrast, the harvest months in Gujarat (and most of India) are characteristically dry. Hence, the option of drying and then storing fodder is possible in India.

The quantity of material usable for fodder is another critical factor that determines when an assemblage becomes stored fodder or immediate fodder. When there is a considerable amount of material that is well dried, then the assemblage is most often stored for later use as fodder. This decision of course is heavily dependent on whether there is other fodder (wild or otherwise) available for the animals at the same time. In general, wild fodder does not store as well as the dry crop harvest residues and therefore when possible, the wild fodders are used first and then crop residues are used. Investment of time and effort in storing fodder is important because it could be used as an indirect indication of the status of animals in the economy. If a crop product is stored for use as fodder later, the implications are that long term planning for animal fodder is a concern, and that the crop byproduct fodder is of value,

however small in quantity it might be.

The location of the processing activities is also a contributing factor for when a crop product or byproduct becomes an immediate or stored fodder. These decisions are related to the investment of time and effort into movement of the materials. If there is a lot of material which is dry and can be used as stored fodder, then effort and time is usually invested into transporting this material to the domicile for storage. If it is fresh and in small quantities then it is most often used as immediate fodder. The decision regarding how much fodder is worth storing is dependent on a wide range of factors.

Whether the farmer has animals or not is an obvious determining factor. However, it is not a direct relationship: i.e. if a farmer does not have animals then he does not use the crop harvest residues (crop products and byproducts) as fodder. In most cases, farmers without animals exchange or give fodder to animal owners, and the key factors mentioned previously (nature of the plant material, quantity of material and location of the processing) determine this exchange.

Incorporation of assemblages and components into dung through tempering or fodder is an important factor to account for the entry of crop byproduct assemblages into archaeological record through secondary pathways. It is important to be aware of such processes in order not to confuse the interpretation of assemblages found in dung fuel. A further complicating factor is the inability to archaeologically distinguish between crop products incorporated into dung through tempering versus through ingestion as fodder. The verification of the crop byproduct use as fodder can be done only through the carbon isotope analysis of the animal bones.

Using the above accessing factors and the patterns observed earlier through data analysis, models for the processing of Sorghum bicolor and Pennisetum typhoides when harvested in type II method are presented in figures 5-6 and 5-7. The models follows

processing pathways that include harvesting in a type II method, threshing with cattle and sticks, winnowings by wind, sieving, winnowings by shaking, pounding, winnowings by shaking, pounding, grinding before preparation for consumption (see also Figures 5-6 and 5-7). Several variations in Sorghum bicolor and Pennisetum typhoides processing pathways are possible. One way is when Sorghum bicolor and Pennisetum typhoides are harvested in a type I method (i.e. when only the panicle heads are cut leaving behind the stalks and all the weeds, thus resulting in a clean harvest). A second way is when byproducts from different processing stages (of both crops) have considerable quantities of desired materials (crop grains). For example if winnowing by wind 1 byproduct has considerable number of unthreshed inflorescence heads and grain. This most often occurs if the wind is too strong or too light. In such instances, the byproduct is not discarded but treated separately through several additional stages (in a parallel pathway) until it can be combined with the rest of the products in the main pathway (Figures 5-3, 5-5). When an assemblage/crop byproduct is sent through a more intensive processing sub-pathway is essentially dependent on the quantities of crop grains in the byproduct assemblage. However, the decision making is based on the experience of the processor, and is also to some degree ethnic group behavior. For example, grain retrieval from byproducts was observed to be more prevalent in Gujarat than in Andhra Pradesh. Similarly, processor decision making is prevalent for fodder usage, and when it is appropriate to winnow by wind versus winnow by shaking. There are definite measurable factors in each of these cases but decision making of the processor is the determining factor. For example, when an assemblage is winnowed by wind is dependent on how strong the wind is at that particular time. However, it is not as simple matter of delaying the processing until the wind is suitable. It is also a matter of whether the processing can wait, whether it is worthwhile to winnow by shaking instead and so on. Such decisions are made by the

processor based on their experience, his/her ethnic group, economic situation, and other factors related to time management.

When Sorghum bicolor and Pennisetum typhoides are harvested in a type I method, this involves the harvest of only the (inflorescence) heads. They are cut from the plant and processed for the grain. This results in a 'clean' harvest where there are no weeds, stalks or straw to be processed out. The resulting processing of these crops involves first the threshing of the heads to separate the grain, and the subsequent processing stages are the same as those presented in the models. The critical difference lies in the compositions of the various crop products and byproducts and these pathways are clearly deductible. Weeds are totally absent, since they were not harvested into the processing pathway initially. Straw is also absent since the Sorghum bicolor and Pennisetum typhoides stalks were not included into the harvest process.

Therefore in the absence of weeds and straw, the discerning components for a Type A harvest of Sorghum bicolor are crop grain with and without husk, Sorghum bicolor rachillas with spikelets and the processed inflorescence heads/rachii. The distribution of these components are included in the model for the processing of Sorghum bicolor when harvested in type II method. Thus, the Sorghum bicolor rachillas with spikelets are processed out significantly through sieving, there is loss of Sorghum bicolor grains with husk and without husk during the winnowing by shaking processes, and the inflorescence heads are processed out in the early stages of threshing and winnowing by wind (Table 5-3). The key to the identification of specific crop products is the overall proportions of the different components.

Similarly for Pennisetum typhoides harvested in a Type A method, particularly in the absence of weeds, the discerning components are crop grain with and without husk, rachii with and without rachillas and rachillas with and without spikelets (Table

5-4). All these components are processed out/selected in the same manner as when the crop is harvested in Type II method. It is possible, however, that there might be a reduction in the number of winnowing by shaking stages since there are no weeds to process out.

Of critical importance is that a Type A crop, such as Sorghum bicolor and Pennisetum typhoides, will never have weeds in crop products at any processing stage when harvested in a type I method. If an assemblage of Type A crop (Sorghum bicolor, Pennisetum typhoides) has weeds associated with it then it is certain that the plant was not harvested in a type I method, and it had to be harvested in a method resembling a type II harvest.

There are two important implications of the models for the processing of Sorghum bicolor and Pennisetum typhoides. First, the composition of the different stage crop products are significantly different and this is direct result of the processing activity. For example, Sorghum bicolor rachilla with spikelets occur in significantly dominant frequencies only in the sieving byproduct. Therefore when an assemblage (archaeological or ethnographic) is dominated by them, this is a strong indicator that there is a very high probability that it is related to a similar process (i.e. sieving) byproduct (Table 5-3, Figure 5-6). When seeds (Sorghum or Pennisetum) dominate an assemblage, for example if the relative proportion of seeds is much higher than other components, then the assemblage could be interpreted as representing a crop product as opposed to a byproduct (Table 5-3, 5-4). Similarly Pennisetum typhoides rachilla without spikelets can be used as a discriminating variable for the crop's winnowing by wind byproduct since they dominate this assemblage significantly (Table 5-4, Figure 5-7).

Second, analysis of the Sorghum bicolor and Pennisetum typhoides processing pathways reveals that the larger undesirable components are processed out in the earlier

stages and the smaller undesirable components (including the weeds) are processed out in the later stages. For example, the large Sorghum bicolor inflorescence heads are definite indicators of lower processing stages such as threshing and winnowing by wind. They however cannot be used as the exclusive isolating variables for archaeological contexts since they are quite unlikely to preserve into the archaeological record (Table 5-3, Figure 5-6). Additionally, the higher the processing stage, the fewer sieve A components in the crop products and byproducts in the Sorghum bicolor processing. In the last few stages (such as winnowing by shaking 1, winnowing by shaking 2, pounding and winnowing by shaking 3), the crop products and byproducts have only sieve B and sieve C components. Similar patterns were also noted for the Pennisetum typhoides processing, where the rachii were clear indicators of the lower processing stages, and they are predominantly processed out through sieving (Table 5-4, Figure 5-7).

TYPE B CROPS: OPPORTUNISTIC CULTIVATION OF Panicum miliare

Introduction

As discussed in chapter 4, 'Opportunistic' Cultivation of two stretches of Panicum miliare along two sides of a river was studied in Andhra Pradesh, South India (Figure 4-12, 4-13). The study plots from the river bank on the side of the village Rapanpalli are termed ROC plots (Rapanpalli 'Opportunistic' Cultivation plots), while the study plots on the banks of the town are called SOC plots (Sironcha 'Opportunistic' Cultivation plots). Study units of typically 25 sq. meters were laid out in the two fields. The plots are characterized as follows: ROC 1 (furthest away from the water); ROC 2 (closest to water); ROC 3 (midway and near a path); SOC 1 (furthest away from water

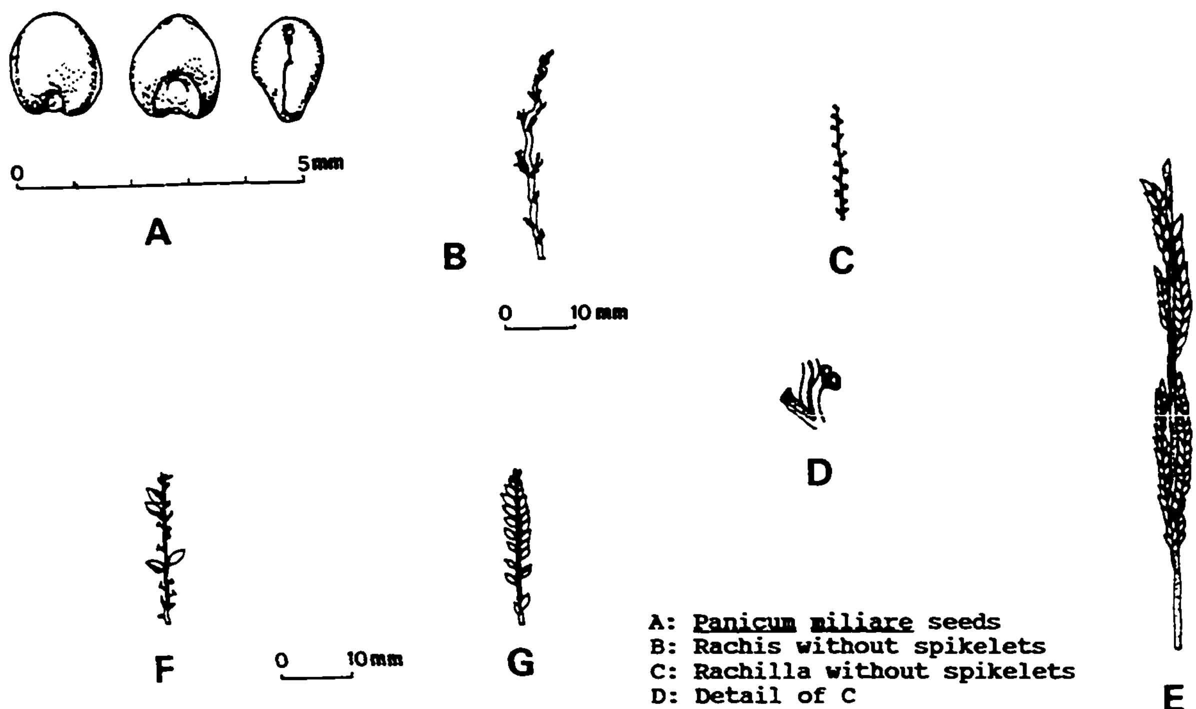
and closest to bank); and finally SOC 2 (closest to water, 3.5 X 7.14m rectangle).

The different plant parts relevant to the analysis of the opportunistic cultivation crop Panicum miliare need to be discussed. In Panicum miliare, the grains are borne at the top of a stem (culm) in the form of a spreading panicle (Figure 5-8). The panicle consists of a rachis with rachillas at each node. The length of the rachillas and the internodes may vary considerably. The rachillas terminate in numerous spikelets and each spikelet consists of 4 thin membranous glumes enclosing two florets of which only one is fertile (Aiyer 1982:91). The fertile floret contains the rounded caryopsis in a shiny lemma and palea (Renfrew 1973). During the processing, the products and byproducts from different stages contain different elements of the plant including: stalks, inflorescence heads (panicles), grain with husk (spikelets), grain without husk, chaff/glumes, straw and rachillas (Figure 5-8).

The data collection and analysis was a two step process. During the first stage of analysis a sub sample was first examined and the different categories were formed by sorting through the material and categorizing each plant part into the relevant botanical classification.

The second stage of analysis entailed the detailed analysis of the rachillas. This was done because, in the absence of weeds, it was evident that the spikelets were the most distinct and potentially distinguishing category. Weeds have been used as indicators of crop processing stages by Jones (1987), however, the absence of weeds in 'Opportunistic' cultivation necessitates that one rely on crop parts for indications of crop processing stages (Hillman 1985; Reddy 1991).

The rachillas were categorized as those with more than 50% spikelets, with less than 50% spikelets, and without spikelets (Figure 5-10). The hypothesis behind this categorization is that the number of spikelet bearing rachillas will increase in the latter stages while the non-spikelet bearing rachillas will be processed out earlier



A: Panicum miliare seeds
B: Rachis without spikelets
C: Rachilla without spikelets
D: Detail of C
E: Panicle
F: Rachilla with < 50% spikelets
G: Rachilla with > 50% spikelets

Figure 5-8. Panicum miliare Plant Showing the Major Components

in the process. This procedure would facilitate more recovery of seeds from the spikelet bearing rachillas in the subsequent processing stages and lower the amount of grain lost.

After the samples were sorted and categorization completed, the data were analyzed for patterns relating to the different processing activities and to isolate categories indicative of a particular processing activity.

First, the raw counts were standardized (see the discussion on standardization for Type A crops). Since there was no significant difference in the compositions between the three plots from ROC (ROC 1, ROC 2 and ROC 3), they were combined into one set. Similarly the SOC plots (SOC 1 and SOC 2) were combined. There are some differences between the ROC and SOC samples which are discussed later in the chapter.

General Patterns

Analysis of the Panicum miliare samples has recognized significant difference in the compositions of different products and byproducts of different stages of processing. These identifiable differences with respect to specific categories are discussed. Three general observations are noted.

First, the higher the processing stage (closer to consumption product) the fewer the categories in the composition analysis. For example there are fewer non-grain components, such as straw, panicle heads and chaff, in the higher processing stages of winnowing II and pounding product. This reduction in the number of categories corresponds to the fundamental principle behind crop processing: to obtain a cleaned crop product, and to do so, the stages closer to the consumption stage have to be cleaner as far as non-grain components are concerned. In addition, the processing activity gets more coercive and focussed on the intense separation of the crop grain

from the non-desirables as the stage gets higher.

The second observation is that categories such as straw and panicle heads are present in significant numbers only in the initial stages such as threshing by-product, threshing product, winnowing I by-product, and winnowing I product. The likelihood of their survival is minimal but their use as fodder is high. The disposal of these categories occurs most frequently in fields (locales away from the home base/settlement) which are very unlikely to be discovered archaeological. In addition, these categories would be preserved only in the likelihood of accidental burning but despite this they probably would not survive the burning due to their fragile nature. Straw would decompose and be undistinguishable, while panicle heads might survive the burning. It is important to note, however, that these two categories play a significant role as fodder. They are given to cattle in the field, and it is possible that the panicle heads or some parts of them could be found in the dung from these cattle. This dung could in some form become part of the home base (eg. dung plastered floors, dung fuels etc.). Therefore, it is important to examine the characteristics of these categories, even if their direct discovery is improbable.

The third observation is that the compositions are likely to differ significantly on the basis of size. Therefore, sieve size could be a determining factor, since each study sample was sieve sorted first to control for size. For example, sieve A components occur significantly only in lower processing stages and are absent in the higher processing stages. This is logically predictable since the larger non-grain material are processed out earlier in the process, while the smaller non-desirables will be processed out later.

Fourth, in the absence of weeds, rachillas are the determining components for identification of processing stages for 'Opportunistic' Cultivation. The total rachillas

(those without seeds and those with less than 50% spikelets) decrease as the stage number increases, whereas the rachillas with more than 50% spikelets increase as the stage number increases. This pattern suggests that the rachillas with more than 50% spikelets are not being filtered out initially in order to facilitate the recovery of seeds from them in the subsequent coercive processing stages. This procedure decrease the amount of grain lost during the crop processing.

Detailed Data Analysis

The data analysis of the 'Opportunistic' cultivation crop processing samples is presented with a detailed discussion of the patterns observed. Later the differences and similarities between stages are discussed, and then the overall results are presented. The concluding segment of this section presents an ethnographic model. The results of the analysis and pattern searching are discussed in the following order: Straw, Panicle Inflorescence, Chaff, Grain with husk, Grain without husk and finally the different types of rachillas.

Straw and Panicles

Straw is present in significant quantities in only two stages: threshing product and winnowing I byproduct (Table 5-5). Of these two stages, the winnowing I byproduct has straw in proportionally higher frequencies as compared to other components. Although straw is well represented in both stages, its distribution varies between sieve sizes. Sieve C straw is absent in winnowing I byproduct, but present in significant quantities in threshing product. This difference could be attributed to the winnowing process which separates the lighter material from the heavier material. In this case the straw was blown off beyond the sample collection area, therefore its notable absence. Although sieve A straw occurs in similar frequencies in both stages,

Table 5-5. Standardized Data of Panicum miliare

Standardized Counts for Panicum miliare
(per 500gms for each stage)

ROC PLOTS	Th prdt	Win(s)Prdt	Win(s)Byp	Win(s)2Prdt	Win(s)2Byp
Straw Vol (ml)	3671	0	4638	0	0
Chaff (vol)	804	0	2500	0	1602.6
Panicles	2	0	3	0	0
Total Rachillas	1974	340	7380	0	0
Rachilla w/o seeds	932	92	4400	0	0
Rachilla w<50% seeds	550	112	1718	0	0
Rachilla w>50% seeds	492	135	1262	0	0
Grain w/husk (spks)	166461	210554	510	56.1	1871.8
Grain w/o husk	0	0	0	552293	1341.6

SOC PLOTS	Th prdt	Win(s)Prdt	Win(s)Byp	Win(s)2Prdt	Win(s)2Byp
Straw Vol (ml)	71	0	1563	0	0
Chaff (vol)	507	0	3750	0	1776
Panicles	12	0	0	0	0
Total Rachillas	124	12	1433	0	0
Rachilla w/o seeds	68	2	850	0	0
Rachilla w/<50% seeds	33	0	246	0	0
Rachilla w/>50% seeds	24	10	338	0	0
Grain w/husk (spks)	190541	223081	2654	53	1364
Grain w/o husk	0	0	0	626298	1064

Key

Threshing Product	=Th prdt
Winnowing (s) Product	= Win(s)Prdt
Winnowing (s) Byproduct	= Win(s)Byp
Winnowing (s) 2 Product	= Win(s)2Prdt
Winnowing (s) 2 Byproduct	= Win(s)2Byp

there is significantly more sieve B straw in winnowing I byproduct. This is due to the breakage of sieve A straw during the winnowing process, specially since the ROC crop was well matured and very dry.

The two assemblages (threshing product and winnowing I byproduct) are also characterized by the presence, albeit in minimal quantities, of panicle inflorescences (Table 5-5). The panicles dominate the threshing byproduct which was not collected for study since the probability of finding and distinguishing it archaeologically is non-existent in South Asia. Panicles in general are significantly more infrequent than in ROC, and occur only in the threshing product. This low occurrence of panicles is because the SOC plants were not dry at harvest time, but were partially green. Thus the panicles were not brittle and did not to break off the plants during threshing (which was done through the rubbing of the panicles between feet). The combination of a partially green crop and threshing by rubbing between feet (which generates less breakage of the inflorescence heads from the rest of the plant), results less straw and panicle heads in the resulting assemblages. In addition, the absence of sieve C straw in any of the SOC samples supports the argument of less breakage due to the above factors.

The presence of straw and panicles only in the initial lower stages of processing such as threshing product and winnowing I byproduct is explained by the basic goal of the processing which is to separate the non-crop grain components from the crop grain components. The logical first step is to separate the biggest and the most obvious components first, and straw and crop inflorescences fall into this category. Therefore, they occur in dominant quantities mainly (only) in the initial processing stages. In addition, the SOC samples illustrate the close correlation of the state of crop at harvest (in this case well dried or partially green) and the threshing type, and the effects on the resulting compositions.

Chaff

The chaff component occurs in all the stages except the winnowing I and II products (Table 5-5). The chaff always occurs in the sieve C. The chaff from the SOC samples is less dry, and had a greener and softer texture. This chaff is more attractive for cattle fodder than the drier ROC chaff, mainly because it is more palatable and digestible. Chaff is a component that cannot be used as an definite indicator of a processing stage, although its absence might be used as a positive sign of the winnowing product assemblage. However, chaff is very delicate, cannot survive high temperatures, and due to its fragility the likelihood of it surviving into the archaeological record is very slim. If one is fortunate enough to find chaff archaeologically, it would be remarkable, and will definitely indicate the associated material to be an uncleaned assemblage. Just because chaff has low potential for archaeobotanists, should not diminish its status as a significant component in crop processing. Chaff is an attractive fodder, and also an attractive fuel for particular activities such as firing of stones to make beads. It is also used as temper in making dung fuel cakes, and used as temper in plastering floors, walls and roofs. Its archaeological discovery might seem unlikely, but its various uses make chaff a valuable component consider while dealing with the question of fodder, and the role of millets and their byproducts in a subsistence economy.

Crop grains with husk

This component occurs in all the stages products and byproducts, albeit only in sieve C and in highly differing quantities (Table 5-5). Crop grains with husk occur in significant numbers in winnowing I product and threshing product. They occur in the other stages but in highly varied frequencies.

Crop grains without husk

Crop grains without husk (dehusked) are very significant for archaeological modeling. They occur at very specific points in the processing: after the dehusking process which done by pounding in 'Opportunistic' Cultivation. The presence of dehusked crop grains indicates that the assemblage is from a higher processing stage, since these grains do not occur in the earlier processing stages. They occur in significant numbers in winnowing(s) II product, although there are some present in winnowing(s) II byproduct (Table 5-5). The presence of dehusked grains reveals two insights in human activities; First, the grain have been processed for human food and are ready for consumption either as grain or for making flour. The second deduction is that they are not being stored for long, since long term storage of Panicum miliare is done in a husked condition. The husk gives the grain protection against fungal attack and moisture, and in a dehusked condition the longevity is problematic.

Rachillas

Distinct patterns in the distribution of all three types of rachillas combined was observed across the processing stages resulting in several conclusive observations. There is a distinct pattern of distribution of all the three types of rachillas between stages. The rachillas occur in significantly higher ratios in the winnowing I byproduct samples while the winnowing I product has the lowest (Table 5-5). This pattern was constant for all three types of rachillas (without spikelets, with <50% spikelets or with >50 spikelets). The samples of winnowing I byproduct are characterized by significantly high frequencies of rachillas of all three types (as compared to other components), while the samples of winnowing I product, winnowing II product and by product, and pounding I product do not have rachillas dominating their asemblages. This supports the hypothesis that as the processing stage increases, the number of

components and the non-grain components decrease. Thus, an archaeological sample of crop type B with a high frequency of rachillas can be interpreted as related to a winnowing I byproduct.

To further examine the distribution of rachillas, pattern searching between rachillas in different sieve sizes was done across all the processing stages. Winnowing I byproduct has the highest percentage of rachillas in each sieve size, which also means they have a higher probability of getting into the archaeological record (Table 5-5). This confirms that there is no sieve size relation factor limiting the dominant occurrence of rachillas in this stage byproduct. Their discovery likelihood is not very high, however, since most often the winnowing process is done away from the home bases. If the winnowing process is done at home bases, then the high frequency of rachillas make winnowing I byproduct a distinct assemblage.

Winnowing I product has the lowest frequency of rachillas, of which most are sieve B size. This pattern implies efficient cleaning of sieve A and sieve C rachillas, but poor cleaning of sieve B rachillas. The reason for this situation is that sieve A rachillas are large enough to be picked out by hand sorting while sieve C ones are small and light, and fly out easily. Thus, sieve B rachillas are more likely to be left behind in the winnowing I product. This distribution pattern is noteworthy and important because it contradicts the logical assumption that the smaller the components (as seen in their sieve size distribution) the less efficient the cleaning process.

The winnowing I byproducts from the two study areas (ROC and SOC) are distinct. The ROC winnowing I byproduct has more sieve B than sieve A or C rachillas, while SOC winnowing I byproduct has more sieve A rachillas followed by sieve B and lastly by sieve C rachillas. For ROC, the pattern is attributed to the brittle nature of the rachillas that are broken in the winnowing process, i.e. sieve A rachillas

of threshing product are getting broken up into the sieve B size rachillas in the processing, creating more sieve B rachillas in winnowing I byproduct. In the SOC samples, the rachillas are not brittle but instead are malleable since the crop was partially mature and greener at harvest. Therefore, in the SOC samples there is no breakage of the rachillas during the winnowing process. This is significant because it is an important isolating characteristic to identify the nature of the crop at harvest time, and this could shed light on other activities such as the type of threshing that was needed.

One important observation is that there are significantly fewer sieve C rachillas in the SOC samples which seem to occur only in the winnowing I byproduct. This pattern may be partly due to the type of threshing done to the SOC samples (threshing by rubbing the panicles between feet). This resulted in less breakage of the rachillas, and just dislodged the seeds from the rachillas into independent spikelets. This patterning has significant implications for interpreting an assemblage with respect to the nature of the original crop at harvest and type of threshing needed.

Rachillas do not occur in winnowing II products or byproducts, and pounding I products or byproducts (Table 5-5). The rachillas occur significantly only in the initial stages of processing. Usually intensive cleaning occurs during the winnowing I process. However, if another cleaning is needed, the process is repeated again prior to pounding and usually through winnowing by shaking. This is not a universal pathway, but it is highly likely that the rachillas noted in winnowing I product will be processed out through winnowing by shaking (different from winnowing II) before pounding I. The disposal of these rachillas will be at the home base, usually in the immediate surroundings of the consumption and domestic activity areas. Therefore, these rachillas have a high fire liability and are important for archaeological modeling.

It is important to emphasize that the processing stages being considered are not

necessarily the absolute and only way the processing is done at any given time. The order of the processing is absolute, but how many times a single process is done (without it being considered a separate process) is very varied from household to household and from region to region. For example, the winnowing I process when done by shaking can occur as a single event or a series of events. Winnowing I is thus done in a graded manner, initially in a less effective manner and then in an intensive manner. This variability does not invalidate the results discussed above, only that one must consider that there might be more than one winnowing I byproduct for a given crop being processed. Each byproduct and product, however, would have the same broad set of characteristics already discussed.

When the distribution of the three rachillas types (without spikelets, with <50%, or with >50% spikelets) between specific sieve sizes were analyzed, a series of patterns were discernible. Similar to the total rachillas patterns, winnowing I byproduct has the highest frequency of rachillas without spikelets (81%), with threshing product (17%) and winnowing I product (2%) in lower frequencies. In winnowing I byproduct rachillas without spikelets occur in higher frequencies in sieve B than in sieve A, and this pattern is consistent with the argument made earlier regarding breakage of rachillas during the winnowing process. There is efficient cleaning of rachillas lacking spikelets during the winnowing process, with winnowing I product having primarily sieve C rachillas, fewer sieve B rachillas and no sieve A rachillas. This trend supports the logical inference that as the sieve size gets smaller the cleaning becomes less efficient. The presence of rachillas without spikelets in the winnowing product (albeit in low frequencies) also reveals that another cleaning was planned before the pounding process.

The rachillas with < 50% spikelets also occur in highest frequencies in the

winnowing I byproduct (72%). The winnowing I product has only sieve B and sieve C components, sieve B having higher frequency than sieve C.

Winnowing I byproduct also has the highest frequency of rachillas with >50% spikelets (67%). Winnowing I product has only sieve B sized rachillas with >50% spikelets, while threshing product has them only in sieve A and sieve B. This differential stage distribution between sieve sizes is interesting because it reflects both the effects of the processing activity and the morphology of the rachillas. The sieve C rachillas with >50% spikelets are absent in the winnowing I product because during the processing activity sieve C rachillas of all the three types were being processed (broken down) into rachillas without spikelets and free grain. This was done by separating the husked grain from the rachillas through manual rubbing of the rachillas against the winnowing basket. The processing ensured a higher retrieval of grain from the non-grain components. This processing creates a low frequency or absence of sieve C rachillas with > 50% and with <50% spikelets.

Summary of Panicum milaire

There are several conclusive statements that can be made through the data analysis and pattern searching of the 'Opportunistic' Cultivation samples.

First, winnowing I product has no any sieve A rachillas and sieve C rachillas occur in very low frequencies. Sieve B rachillas occur in the highest frequencies. Of the three types of rachillas in sieve B, those with >50% spikelets occur in the highest frequencies, and would be most indicative of winnowing I product when they occur associated with husked grain, and an absence of straw, panicle inflorescences or chaff. This pattern is due to several factors. First, sieve C rachillas in general are present in lower frequencies (specially in the SOC samples) due to the non brittle nature of the rachillas. Second, sieve A rachillas are easier to clean out by hand selection since they

are more visible. And lastly the rachillas with > 50% spikelets are difficult to clean because they have considerable grain, and most often the processor tends to keep these rachillas until the ultimate processing stage in order to retrieve more of these grains. This is in stark contrast to the handling of the rachillas without any spikelets which are processed out almost instantly if they are visible.

In winnowing I byproduct the rachillas occur in very high frequencies, with rachillas without spikelets dominating. Certainly, the winnowing process is efficient in cleaning out the rachillas. The process of cleaning along with the effort to separate crop grains from the rachillas creates a differential treatment of sieve C rachillas during processing. Sieve B rachillas with > 50% and < 50% spikelets are not treated in the same manner and this significant differential treatment can be used to distinguish the processing stage. When sieve B rachillas with spikelets occur in dominating frequencies then the sample could be related to a winnowing I product. In contrast, a winnowing I byproduct sample has more sieve B rachillas without spikelets.

Conclusions of Panicum milare analysis

Using the rachillas data distributions it is possible to define certain patterns which are indicative of assemblages pertaining to threshing product, winnowing I byproduct and winnowing I product. The winnowing II product and byproduct, on the other hand, can be distinguished on the basis of the distinctive ratios of crop grains with husk to those without husk, and chaff.

Winnowing I product and threshing product are two assemblages that have a higher likelihood of being discovered archaeologically, particularly as compared to winnowing I byproduct. Winnowing I product can be distinguished from threshing product based on the following distinctions:

(1) Threshing product has sieve A rachillas and rachillas with <50% spikelets while both are absent in winnowing I product.

(2) Winnowing I product has a significantly lower frequency of rachillas without spikelets as compared to threshing product.

(3) Most importantly, winnowing I product has a greater crop grain to rachillas ratio than threshing product. In other words, there are fewer rachillas to crop grain in the former assemblage, while the number of rachillas to grain in threshing product is significantly higher.

Even though winnowing I byproduct has a lower likelihood of being discovered archaeologically, it is important to present its distinguishing characteristics as they pertain to rachillas. This assemblage has sieve C rachillas which are absent or occur in significantly lower frequencies in the other assemblages. The assemblage also has a high percentage of rachillas without spikelets. Most importantly, the ratio of crop grain to rachillas is very low, i.e. there are a lot of rachillas for each grain, and this characteristic sets this assemblage apart from threshing product and winnowing I product.

Differences between ROC and SOC

The main difference between the samples from the two areas, the Roc study plots and the SOC study plots, is the maturity level of the crop at the time of harvest. In addition, the two study plots were threshed in two differing methods. These two differences have ramifications for the compositions of the crop products at various stages.

There is more loss of crop grain in the ROC samples than the SOC samples. This is due to the brittle well matured dried panicle in the ROC samples. The maturation condition of the crop plants at the harvest has direct effects on the yields.

The yields from the two study area plots differ in that the SOC plots have a better yield than the ROC plots.

In general, the SOC sample processing was more labor intensive, but with a corresponding lower rate of grain loss. This is a direct result of the maturity of the crop plant at the time of harvest.

The byproduct from the threshing process of the SOC samples is more suitable for cattle fodder since it is greener and has less celluloid, and this is easily digestible. The ROC threshing byproduct is totally dried, harder to digest, and less attractive as fodder, although it was fed to animals. Certainly, the greener SOC threshing byproducts are more popular than the ROC threshing byproducts for fodder.

The general cleaning process is easier for the SOC samples, essentially because there are significantly fewer rachillas in the crop product which need to be processed out. Additionally there are fewer inflorescence heads to be cleaned for the SOC samples as compared to the ROC samples. This is a direct result of the maturity of the crop during harvest and the threshing method used. Threshing by rubbing of the seed bearing panicle inflorescences between the processor's feet can be done only when the plant is not too mature, and this method of threshing yields less breakage of the rachillas. The rubbing dislodges the seed from the rachillas rather than breaking the rachillas from the inflorescence heads as it occurs when threshing with a stick. The latter method of threshing is done when the crop plants are well-matured. Thus the combination of the level of maturity (high maturity) and threshing with sticks contributes to there being higher numbers of rachillas in the crop products for the ROC samples. This requires more cleaning processing, particularly in the latter stages.

Since the SOC grains are fresher, roasting is a useful technique for the separation of the husk/glumes from the grain. Thus, there is a higher likelihood of the

SOC crop grain being subject to accidental fires because they are roasted before the pounding stage. Spillage during roasting (a very likely scenario) would carbonize the grain and increase their chance of survival into the archaeological record. Crop grains from the ROC samples do not need to be roasted before pounding, since they are well dried. Thus, there are fewer chances of the crop grains from the ROC samples being subject to accidental fires.

If there were weeds associated with these samples, their inclusion into the crop products would vary depending on whether the crop plants were harvested ripe or green, and then how they were threshed. For example, if the crop plant was harvested green and threshed by rubbing the inflorescence panicles between feet, then only the weed that were tall enough to reach the height of the inflorescence heads at the time of harvest would be included in the threshing. Thus, only a limited number of a specific type of weeds (erect weeds) would enter the processing pathway. In contrast, if a crop plant was harvested in a well matured condition and threshed by using sticks, then all the weeds growing in the plot would be included into the threshing (since the harvesting is a Type II harvest). Thus, the range of weeds being included into the processing pathway would be greater. This is a very important issue to take into consideration when modeling for archaeological interpretations, and one way to avoid the possibility misinterpreting the presence or absence of weeds is to examine the nature of the weed plant morphology (i.e. if they are prostrate type, erect, both etc.).

An Ethnographic Model for the Processing of Type B Crops without Weeds (Panicum miliare)

Patterns in the distribution of crop components between processing stages discerned through data analysis are summarized in table 5-6. These results form the foundations of an Ethnographic Model for the Processing of Type B crops without

Table 5-6a. Tabulation of Panicum miliare pattern of distribution

STAGES	Straw	Chaff	Panicles	Rachillae	Rachillae w/o	Rachillae w/ <50%	Rachillae w/ > 50%	Spikelets w/ husk	Grain w/o husk
Th Prd	--	--	--	--	--	--	--	xxx	o
Win(s) 1 Prd	o	o	o	--	--	--	--	xxx	o
Win(s) 1 ByP	xx	xx	--	xx	xx	x	x	x	o
Win(s) 2 Prd	o	o	o	o	o	o	o	--	xxx
Win(s) 2 ByP	o	xx	o	o	o	o	o	xx	xx

o = Absent (0%)
-- = Rare (0-1%)
x = Moderate (2-11%)
xx = Strong (11-50%)
xxx = Dominant (50-100%)

Table 5-6b. Tabulation of Panicum miliare rachillae distributions by sieve size

STAGES	Total Rachillae			Rachillae w/out Seeds			Rachillae w/ <50%			Rachillae w/ >50%		
	A	B	C	A	B	C	A	B	C	A	B	C
Th Prd	x	x	--	x	x	--	x	--	--	x	--	o
Win(s) 1 Prd	o	--	--	o	--	--	o	--	--	o	--	o
Win(s) 1 ByP	xx	xxx	x	xx	xx	x	x	x	--	x	x	--
Win(s) 2 Prd	o	o	o	o	o	o	o	o	o	o	o	o
Win(s) 2 ByP	o	o	o	o	o	o	o	o	o	o	o	o

o = Absent (0%)
-- = Rare (0-2%)
x = Moderate (3-15%)
xx = Strong (16-35%)
xxx = Dominant (36-100%)

weeds (Figure 5-9), exemplified by Panicum miliare when it is grown in conditions where there are no associated weeds, and it is processed through threshing with sticks and rubbing of feet, winnowing by shaking and pounding. The table was developed by combining the standardized counts from the two different field locations (ROC and SOC), and then their distributions were collapsed into five ranges which were given qualitative terms, ranges and symbols (the ranges vary depending on the data being tabulated for modeling).

As discussed for the Type A Model, four additional factors instrumental in accessing the probability of an assemblage entering the archaeological record gave tobe considered. The four factors are: likely to be prone to accidental and intentional fires (from degree of very likely to low likelihood), storage of crop product (likely or definitely), fodder popularity (immediate or stored) and inclusion or not into animal dung as temper.

One important distinction of Panicum miliare from the storage of Type A crops, is that in the case of Panicum miliare, the risks of fungal and bacterial infection increase as the crop product gets closer to consumption stage, since it is dehusked in these later stages and is vulnerable to such infections. The husk of the grain provides a protective covering, and in its absence, the grain is exposed to infections. In most cases therefore, the transport of grain (particularly to long distance markets) occurs when the grain is still husked. Thus, transport has to occur right after or right before the roasting stage. This pattern has considerable applicability to archaeological interpretation since it provides insights into the ramifications of processing stages with respect to economic processes such as the trade of crop grain.

A model for the processing of Panicum miliare (type B crop without weeds) is presented in Figure 5-9 (see also table 6a and 6b). The processing pathway is very straight forward, consisting of Harvesting, Drying, raking, winnowing 1 by shaking,

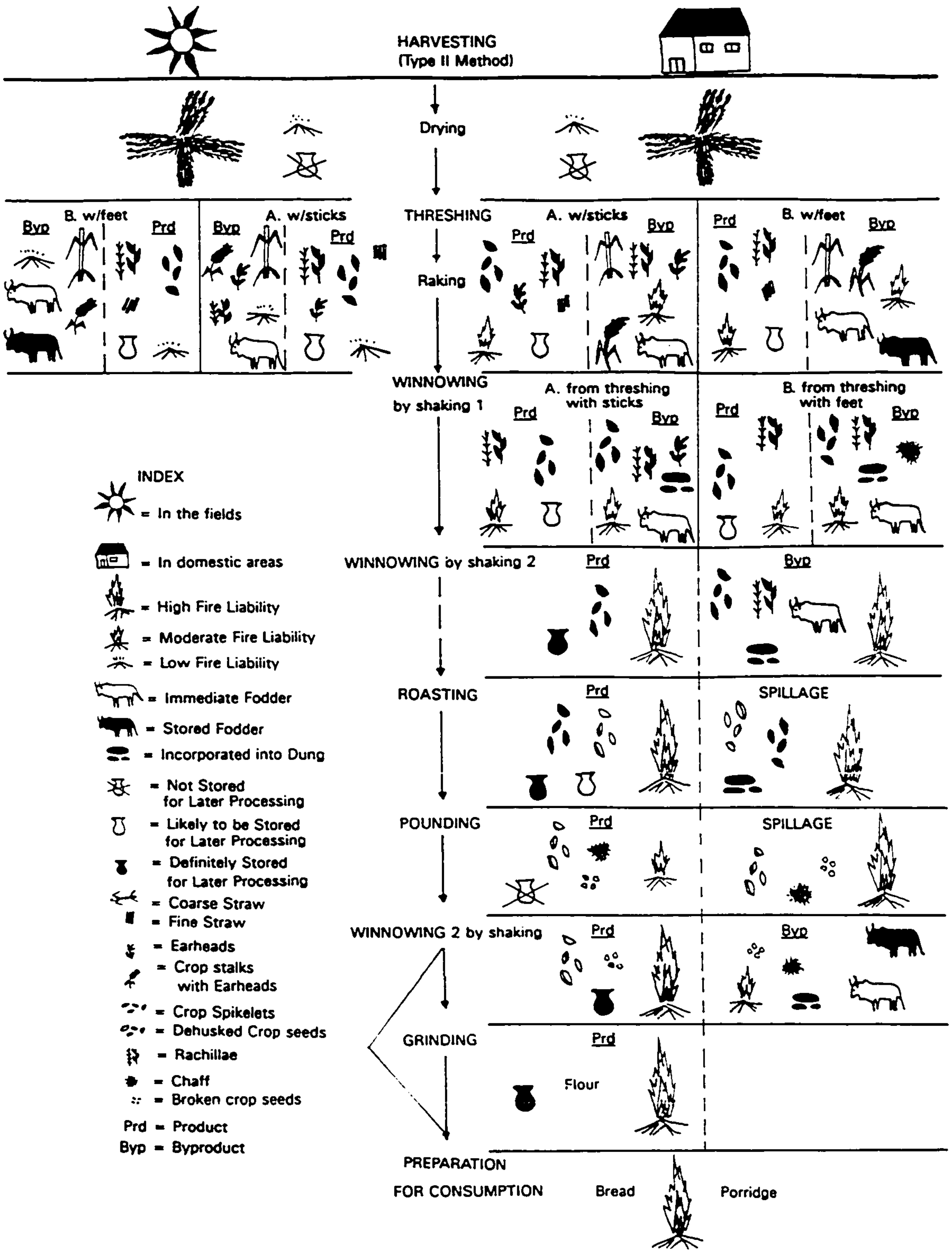


Figure 5-9. Model for Panicum miliare

Roasting, pounding, winnowing 2 by shaking and grinding, followed by consumption preparations. Several implications are summarized from the model. First, there are specific variables that distinguish the different stages products and byproducts. For example crop grains with husk occur in significant frequencies in winnowing I product and threshing product, while crop grains without husk occur in significant frequencies only in winnowing II product. Thus ethnographic or archaeological samples showing similar patterns could be interpreted as being most likely related to the particular stage products. Similarly, rachilla in general (and particularly those without spikelets) occur in significantly higher ratios in the winnowing I byproduct, and are strong indicators of this assemblage (Table 5-6, Figure 5-9).

Second, in the ethnographic situation, weeds were notably absent, due to the nature of the soils, and therefore the processing model emphasizes other components such as rachillas as indicators of processing stages crop products and byproducts. Rachillas are distributed in a patterned manner between stages and can be used as definite indictors (Table 6b). Figure 5-9 graphically shows how rachillas fall out in a specific patterned manner in the processing pathway. For example, winnowing I byproduct is characterized by significantly dominating frequencies of rachilla without spikelets (Table 5-6), while winnowing I product is characterized by high frequencies of sieve B rachilla with >50% spikelets.

Among the processing stages where rachillas could be potentially distinctive isolating variables, threshing product and winnowing I product are the most likely to survive into the archaeological record and be discovered. This is because winnowing I product is often stored in home bases/ domestic areas which most often discovered and excavated. Threshing product is also occasionally stored in domestic areas/ home bases for later processing when other pressing work is present or bad weather occurs. Due to their proximity to domestic areas, their assemblages are more prone to accidental

burning in specific contexts and survive into the archaeological record. Given this situation, these two assemblages can be distinguished using the rachilla data. First, the threshing product has sieve A rachillas, while winnowing I product lacks this size rachillas. Second, a higher percentage of sieve rachillas B without spikelets occur in the threshing product sample, while winnowing I product is dominated by sieve B > 50% spikelets rachillas. Most importantly, the ratios of rachillas to husked crop grains is higher for threshing product than winnowing I product. This last pattern is the most distinct feature that can be used to differentiate the two assemblages.

The winnowing byproduct assemblage has a lower probability of being discovered archaeologically because more often the winnowing I process (by wind and shaking) occurs away from the home/domestic areas. If it does occur in the home/domestic areas, then this assemblage is most often fed to the cattle, and it does not make it into the archaeological record as a distinct assemblage, but some components could survive archaeologically in dung fuel, or in dung plastering material. Thus, it is important to discuss the distinguishing rachillas which will identify the assemblage. The most important feature is the high ratio of rachillas to husked grain. This pattern of many rachillas and few grains is just the opposite of a threshing product. The rachillas also will be characterized by a predominance of sieve C sized ones, particularly > 50% spikelet rachillas.

Third, no one variable can be used in isolation to define a particular processing stage or stage product or byproduct, but it is a combination of various components in relative proportions that are used as indicators.

TYPE B CROP PLANT WITH WEEDS: Setaria tomentosa

During the study of crop processing of summer monsoonal crops in Gujarat, the processing pathway of a plot of Setaria tomentosa was also studied. This was done to compliment the crop processing study of Panicum miliare, which was a Type B crop but due to the particular cultivation ('Opportunistic' Cultivation) did not have any associated weeds. The study of one plot of Setaria tomentosa, provides insight into the crop processing of a Type B plant with weeds associated. For the purpose of this study, Setaria tomentosa is treated as a Type B crop plant, since its morphological characteristics are the same. In reality it is a weed associated with disturbed areas and millet fields. In addition, this study can also be used to build models for the cultivation and processing of a wild/undomesticated plant.

Setaria tomentosa is a small seeded annual grass which can be often found growing wild in the back gardens of village houses (Vishnu-Mittre and Savithri 1976:560). Its seeds are significantly smaller than those of Pennisetum typhoides and Sorghum bicolor. The grass is eaten by cattle, and its growth correlates well with the monsoon season. It is considered a drought resistant plant useful for its grain and more importantly it is used as fodder (Figure 5-10).

In the study field, high concentrations of Setaria tomentosa occurred along the edges of the Sorghum field in a visually distinct 6 to 7 meter wide and 9 to 10 meter long strip (see figure 4-4). Interviews with the farmer revealed that the strips of Setaria tomentosa were not an intentional part of the Sorghum field, but were essentially growing as weeds in fallow areas. The few Sorghum plants growing in the Setaria tomentosa strip were intrusives from last year, or spillage during the sowing of the Sorghum field itself and constitute less than 20% of the plot's plants. The Sorghum plants in this plot were very thin, i.e. the stalks were very much like Type B crops. Therefore the harvesting was done in the Type II manner. This provided an opportunity

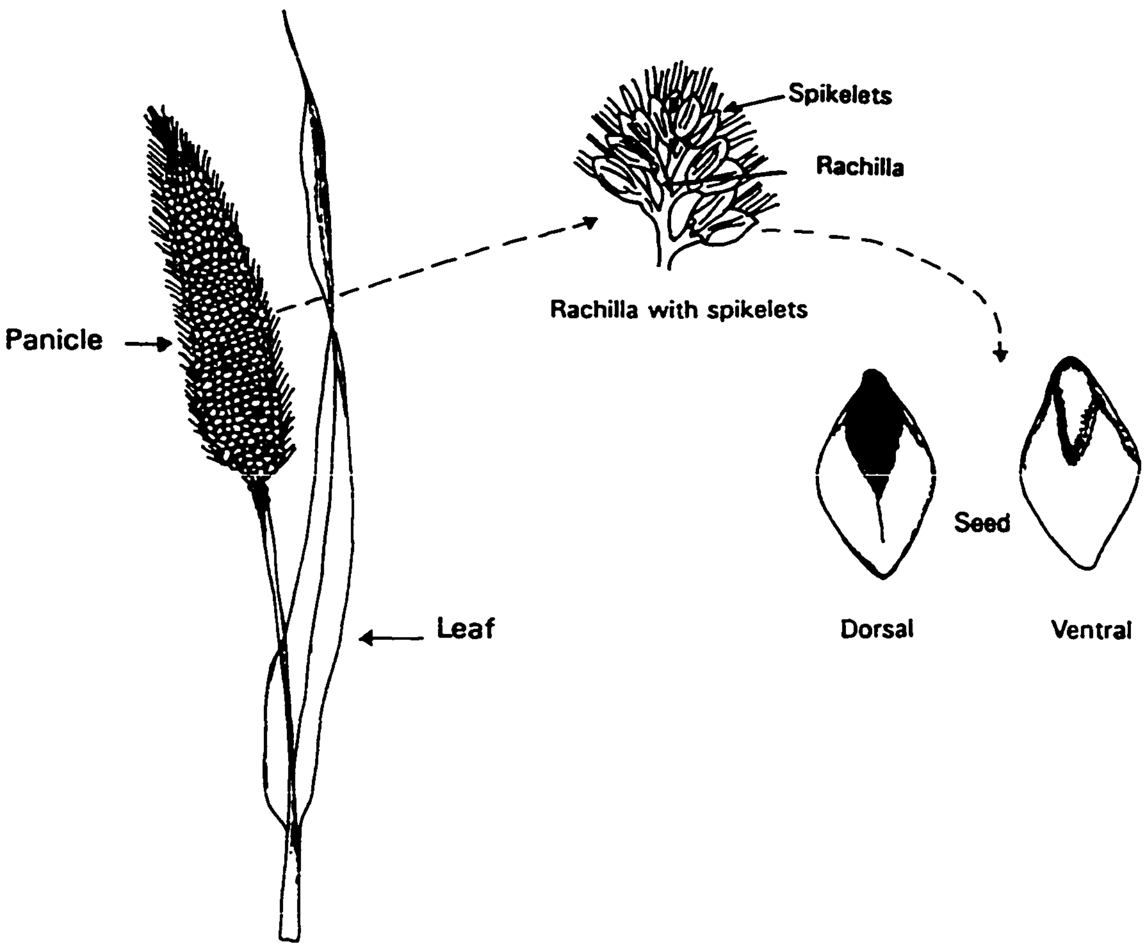


Figure 5-10. Setaria tomentosa Plant Showing the Major Components

to examine how two different crops are processed using the same pathway.

The Setaria tomentosa study plot was close to the cattle shed, the well and adjacent to a pathway in the farmstead. The plot was studied in the manner as those of the other crops addressed in this project. The plot was harvested in a Type II method, with a number of plants gathered at the base and cut with a sickle.

Although Setaria tomentosa is a weed for the purpose of processing, the farmers treated it as a crop plant. There were 4 processing stages for Setaria tomentosa: threshing with sticks, sieving, winnowing by shaking and pounding. This processing pathway closely mirrors that of Chenopodium album (another type B crop), which is cultivated in the area as both human food and animal fodder. The processing stages and the different methods of crop processing (threshing with stick, sieving and winnowing by shaking) were not any different from those done for Sorghum and Pennisetum, and are not discussed again for Setaria tomentosa.

Data Analysis

The samples collected had components of all the three sieve sizes (A, B and C), except winnowing by shaking product and byproduct which had components of only sieve size B and C. The different components distinguished during composition analysis of the samples from Setaria tomentosa crop processing are: Straw, Setaria tomentosa rachillas, Setaria tomentosa seeds, Sorghum rachilla with spikelets, Sorghum inflorescence heads, Sorghum grain with husk and without husk and an array of weeds.

Straw

Straw occurs in dominant proportions in the sieving byproduct and in strong frequencies in the winnowing by shaking byproduct (Table 5-7). Straw as a component

Table 5-7. Standardized Data of Setaria tomentosa

Standardized Counts for Setaria tomentosa
(per 500 gms for each stage)

	Siev Prdt	Siev Byp	Win(s)Prdt	Win(s)Byp
Straw Vol (ml)	7428	82970		12500
Sorg.rachilla w/spk		1500		
Sorg.infl.heads	29	1872		
Sorg.w/husk (spks)			500	
Sorghum grain	4142	137	5292	600
Setaria rachilla	9943	954		14450
Setaria seeds	3483914.2	9926	1809035	623300
Weeds #	407337	23607	208247	91200
Amaranthus sps (SFH)	11486		8946	2800
Carvia sps (SHH)		23		
Dactyloctenium spks (SHL)		4159		
Dactyloctenium sps (SFL)	205828.6		110416	11200
Digera sps (SFH)	87424	17425	75315	70100
Digiteria sps (SFH)	371	159	353	
Eragastis spk (SHL)	92571	1046	946	
Eragastis sps (SFL)		409	7239	
Hieracium sps (SFL)	343		353	
Hylandia sps (SFH)			29	
Indigofera sps (SFH)			235	
Iseilema sps (SHL)		23		
Lepidium sps (SFH)			471	
Phyllanthus sps (SHH)	800		530	400
Trianthema sps (SFH)	7771		3414	6600
Trianthema w/rachus (SHH)	686	23		100
Triumfetta sps (BHH)		91		
Vernonia sps (BFL)	57	250		
Total SFH Weeds	107052	17584	88763	79500
Total SHH Weeds	1486	46	530	500
Total SFL Weeds	206172	409	118008	11200
Total SHL Weeds	92571	5228	946	
Total BFL Weeds	57	250		
Total BHH Weeds		91		

Key

Sieving Product = Siev Prdt
Sieving Byproduct = Siev Byp
Winnowing (s)Product = Win(s)Prdt
Winnowing (s) Byproduct = Win(s)Byp

SFH = Small Free Heavy
SHH = Small Headed Heavy
SFL = Small Free Light
SHL = Small Headed Light

BFL = Big Free Light
BHH = Big Headed Heavy
BHL = Big Headed Light

cannot be used as one of the strong indicators of processing, mainly because due to its nature it has low probability of surviving into the archaeological record. Nonetheless it is an important component because of its use as fodder for animals.

Sorghum inflorescence heads

Sorghum inflorescence heads occur significantly in the sieving byproduct, and rarely in sieving product (Table 5-7). This component is processed out in the initial stages mainly because of its size (all are sieve A size category), and rarely makes it to a latter stage. The inflorescence heads could be used as definite indicators of initial processing stages if they are found archaeological contexts.

Sorghum grain with husk

Sorghum grains with husks occur only in the winnowing by shaking product (Table 5-7). They are not processed out in the sieving or winnowing. There is obvious selection for these grains by the processor despite their low frequencies. They are not selected out because they occur in manageable frequencies (in the processor's perspective) and they can be dehusked manually in the winnowing basket during the winnowing by shaking process.

Sorghum grain without husk

Sorghum grain without husk occurs in significant frequencies in three samples: sieving product, winnowing by shaking product and byproduct (Table 5-7). The high frequencies in sieving product and winnowing by shaking product are expected, since they are being selected. The high frequencies of Sorghum grain in the winnowing by shaking byproduct is unexpected, and indicates loss of grain in the winnowing process, suggesting an inefficient process or processor. Detailed examination of the Sorghum

grain in the winnowing by shaking byproduct reveals that the most of the grain (over 75%) are the tail grain and defective grain (inflected with fungus or decayed). So in actuality the winnowing process is efficiently removing unsuitable crop products.

Sorghum rachilla with spikelets

Sorghum rachilla with spikelets occur in threshing product and sieving byproduct, which demonstrates that the use of an ethnographic sieve efficiently separates them from the crop product sample. Thus, Sorghum rachilla with spikelets can used as indicators for sieving byproducts and, of course, threshing product).

Setaria tomentosa rachillas

Setaria tomentosa rachillas occur significantly in sieving product and less significantly in winnowing by shaking product (Table 5-7). Thus, the rachillas are cleaned initially in the sieving, but primarily in the subsequent winnowing by shaking process. Therefore, Setaria tomentosa rachillas can be indicators of these two processes byproducts.

Setaria tomentosa seeds

Setaria tomentosa grain/seeds occur in significant frequencies in sieving product, winnowing by shaking byproduct and product. As in the case of Sorghum, their presence in high frequencies in the sieving and winnowing by shaking products is expected, and the high numbers in winnowing by shaking byproduct and moderately numbers in sieving byproduct is a unanticipated. Therefore, the Setaria tomentosa in the winnowing byproduct and also in the sieving byproduct, were examined for distinguishing characteristics. As in the case of Sorghum grains, the majority of the

Setaria tomentosa seeds from winnowing by shaking byproduct were either tail grains or were inflected by fungus or were rotten. Most of the grains in sieving byproduct had rotted badly and had swelled in size.

Weeds

The twenty different weed species of the Setaria tomentosa plot are present in moderate amounts and are categorized into 7 categories (Table 5-7). The categories present were Big Headed Light (BHL), Big Headed Heavy (BHH), Big Free Light (BFL), Small Free Light (SFL), Small Headed Heavy (SHH), Small Free Heavy (SFH) and Small Headed Light (SHL). All categories are represented except the big free heavy weed category (BFH). Of all the categories, the small free light (SFL) and small free heavy (SFH) dominate the weed assemblage (86%), followed by big headed light (14%). The other categories, big headed heavy (BHH), big free light (BFL), small headed light (SHL) and small headed heavy (SHH), occur in low frequencies (.3%). In general, the free weed seeds occur in significantly higher frequencies (86%) than the headed weeds (14%). This reflects the efficiency of the threshing process.

The patterning of the weed categories down the processing pathway is intricate in that the different categories occur in differing frequencies at different stage products and byproducts. For example, small headed light weeds (SHL), big free light weeds (BFL) and big headed heavy weeds (BHH) occur only in sieving byproduct. The small free heavy weeds (SFH) are present in all the stages byproducts and products, but occur in significantly higher frequencies only in winnowing byproduct. This reflects their removal through the winnowing process. Small free light weeds (SFL) remain into the winnowing product, and are removed only through later winnowings. Thus, the distribution of weed categories occurs in varying levels of significance at different processing stages, and therefore they can be used as indicators of these processing

stages products and byproducts.

A model for the Processing of Setaria tomentosa

The data regarding the patterns of component distribution is summarized in table 5-8. Their distributions were collapsed into five ranges which were given qualitative terms: absent (0%)/ O; rare (0% - 7%)/ -; moderate (8% - 20%)/ x; strong (21% - 60%)/ xx and dominant (61% - 100%)/ xxx. This table provides is the skeleton for modeling crop processing of a Type B crop such as Setaria tomentosa, through threshing with sticks, sieving and winnowing by shaking.

The four factors which are instrumental in accessing the probability of these components entering into archaeological contexts are then considered. They are fodder use (immediate or stored), storage of crop product (likely or definitely), prone to fire, catastrophic and intentional (degree of very likely to low likelihood) and lastly incorporation into dung as temper or fodder and its subsequent use as fuel.

In the case of husked crop grains such as the Setaria tomentosa storability is optimal until the pounding stage when the grains are dehusked. So, the storability index (NSLP, LSLP or DSLP) for millet crops such as Setaria tomentosa and Panicum miliare would also be a good indicator for when a crop could be best transported to distances, i.e. to markets. The degree of exposure of a crop product or byproduct to fire, catastrophic and/or intentional, is probably the most important factor which determines the survival of the assemblage(s) into the archaeological record.

A model for the processing of Setaria tomentosa is presented in figure 5-11. The processing pathway is simple with harvesting, raking, threshing, sieving, winnowing by shaking (1) and winnowing by shaking (2) being the main processing stages. There are no variations in the pathway; however, there are additional processing stages after

Table 5-8. Tabulation of Setaria tomentosa pattern of distribution

STAGES	Straw	Sorghum panicles	Sorghum grain w/ husk (spks)	Sorghum grain	Setaria rachillas w/ spks	Setaria grain w/ husk	Setaria rachillas	Total Weeds	BHL	BHH	BFL	SFL	SHH	SFH	SHL
Sieving ByP	xxx	--	o	--	--	x	--	xx	xx	--	--	--	o	xxx	--
Siev Prd	--	--	o	--	o	xxx	--	x	xx	o	--	xx	--	xx	o
Win(s) ByP	--	o	o	--	o	xxx	--	x	o	o	o	x	--	xxx	o
Win(s) Prd	o	o	--	--	o	xxx	o	x	--	o	o	xx	--	xx	o

o = Absent
--o = Extremely rare
-- = Rare
x = Moderate
xx = Strong
xxx = Dominant

SHH (small headed heavy)
SHL (small headed light)
SFH (small free heavy)
SFL (small free light)
BHH (big headed heavy)
BHL (big headed light)
BFL (big free light)

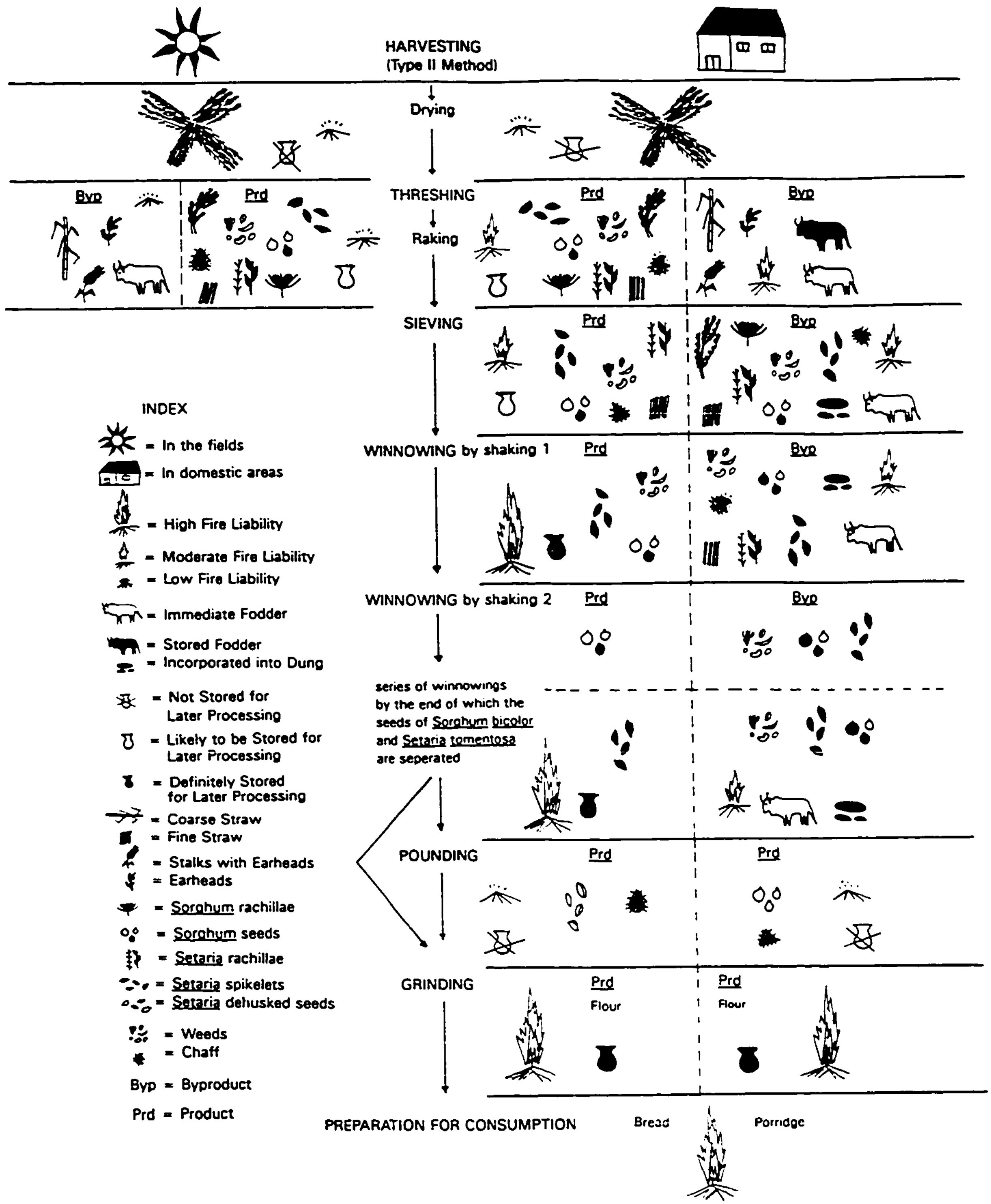


Figure 5-11. Model for Setaria tomentosa Processing

winnowing by shaking (2) which are not presented in the model. These additional stages include a series of additional winnowing by shaking stages, which clean out the crop product more efficiently each time. The successive winnowing by shaking process also separate the Sorghum and Setaria tomentosa. For the latter, winnowing by shaking is followed by pounding when the grain are dehusked. Often at this stage, the grains are roasted to facilitate the removal of the husks during the pounding process. Then, another winnowing by shaking removes the chaff-husk from the dehusked grain. Since the grain can be consumed in both grain and flour form, grinding occurs only when the consumer needs flour. In the case of Sorghum, the grain are ground to a flour after winnowing by shaking and before consumption.

From this model processing for a Type B plant (in this case Setaria tomentosa) it is evident that the smaller the crop grain seed being selected for in the crop processing stages, the higher the number of smaller sized weeds left behind for later crop processing stages. This pattern occurs because these smaller weeds are difficult to process out from grain seed particularly when they have other properties in common. Big weed seeds are absent in the winnowing product, and small headed weed seeds are rare. In contrast, small free weed seeds, which are closest to Setaria tomentosa in morphology, are left behind with the crop grains (Table 5-8, Figure 5-11). Thus the remaining small free weeds are processed out in the last few series of winnowing I, and this is very important for archaeological modeling. Therefore, the weed seeds that most closely resemble the crop seed are the last to be processed out. Using this information about the Small Free Heavy weeds similarity to Setaria tomentosa, if there were big, free, heavy weeds such as Cordiosperum or Lannea coromandelica present in this sample, then I would predict they would remain into the winnowing product since they are similar in morphology to Sorghum grain.

Lastly, it is apparent that a processor does not have to be selecting for only one

type of grain (i.e. only Sorghum). This study demonstrates that processing can occur reasonably efficiently when the processor is selecting for two different types of grains with different morphological characteristics in the same sample. The efficiency of the processing is definitely lower than if they were two separate samples, but it is done with acceptable efficiency. This observation has important archaeological implications. For example, if one recovers an assemblage with high concentrations of two different plant species, one cannot immediately conclude that one species is necessarily a weed. In the case of Sorghum and Setaria tomentosa (where Setaria is not considered a crop), Sorghum could be used as a staple crop and Setaria tomentosa could be used as starvation food. Since they grow together, they were harvested and processed together, and separated only in the last few processing stages. Setaria tomentosa is also used as fodder for cattle.

IMPLICATIONS FOR ARCHAEOLOGICAL INTERPRETATION

This concluding section of the chapter discusses two methodological issues, summarizes the salient aspects of the models, and discusses the variations in processing when crops (Type A and Type B) are cultivated for three different purposes; for only food, for food and fodder or for only fodder.

Methodological Issues

There are two main methodological issues relevant to archaeological modeling that need to be clarified (1) possible differences in processing pathways and their implications to the models presented, and (2) the effect of formation processes on the preservation of specific components, and their distribution in different sieve sizes.

Variations in crop processing occur within each processing stage of the

different crops, but the sequence of stages in the pathway does not vary. Thus, threshing is always followed by winnowing, which is followed by sieving, and so on. There is no variation in the course of the pathway itself, but there is often a choice of what type of processing one does within one processing stage. For example, threshing can be done by cattle, sticks, or by feet. Winnowing can be done by wind or by shaking. A processor's choice of a certain type of threshing or winnowing is based on several factors including the type of crop being processed, amount of material being processed, availability of processing tools and man power, and wind velocity for winnowing by wind.

The ethnographic models developed for processing of various crops in this project include different types of threshing and winnowing. However, if threshing and winnowing differed archaeologically from those presented in the model, one might suggest that this would affect the modeling. Careful consideration of the parameters of processing methods reveals that a distinct model need not be developed for each particular situation. The models developed in this chapter are flexible to accommodate variations in the processing. In addition, such differences should have observable indicators in the various threshing and winnowing products and byproduct.

Threshing can be done through the use of cattle, sticks, and rubbing of the panicle inflorescence heads between the feet. These three threshing methods are different activities and this effects the material being processed (refer to 'Opportunistic' cultivations of ROC and SOC which were threshed by two different methods). The most important difference is in the quantities of rachillas that are broken off during the different threshing processes. Threshing by sticks and cattle results in more breakage of the panicles and rachii and also a greater loss of crop grain in the byproduct, which then means higher frequencies of rachillas in the successive processing stages. Threshing through rubbing of panicles between the feet results in fewer rachillas in the

product and also less loss of grain in the byproduct. As discussed for 'Opportunistic' cultivation, however, the selection of the threshing is based the on nature of the crop plant, particularly whether it is dry or green.

Winnowing can be done through the use of wind and through shaking. Processing through winnowing by shaking is a more directed intensive separation process as compared to winnowing by wind. It is important to note that small seeded crops are not winnowed by wind, since there would be a resulting loss of crop grain. Thus, it is mostly the larger and medium sized grain that are winnowed by wind. In this project, the larger grained Sorghum bicolor and Pennisetum typhoides were winnowed by wind in addition to winnowing by shaking, while the smaller grained Panicum miliare and Setaria tomentosa were winnowed by shaking only. Therefore, when dealing with a small sized crop grain, it can be automatically deduced that it was not winnowed through wind.

Therefore, sorting out the effects of winnowing by wind and through shaking on the stage processing is only relevant to the crop plants with bigger sized grains such as Sorghum bicolor and Pennisetum typhoides. I suggest that in a majority of cases the first winnowing (usually directly following threshing in the fields) is always by wind, unless there are extenuating circumstances making it impossible. When threshing products are first winnowed by wind, the processing is more efficient than if they were only winnowed through shaking. Doing winnowing by wind first makes the successive winnowings by shaking more efficient, since it cleans most of the chaff, straw and inflorescence heads. Such cleaning by shaking would be more time consuming. These components are easier to clean out through winnowing by wind because they are light and their separation is facilitated efficiently by the wind. If winnowing by shaking was the initial winnowing then the separation of these components becomes very labor

intensive since shaking (tossing and tapping) is not as effective in separating light materials.

When winnowing by wind and shaking are not done as successive processes, the compositions of the byproducts are distinctive and can to differentiated. The winnowing by wind byproduct has more prime grain (there is a greater loss of grain), and also more small weeds. Winnowing by shaking byproduct, however, has fewer prime grain, more tail grain and fewer small weeds (because they are harder to process out through shaking). It is important to note that winnowing by wind will never replace any later winnowing by shaking processes. The only processing stage where there could be a choice of winnowing is the first winnowing. However, it is very rare that winnowing by wind in this initial stage is replaced through winnowing by shaking. Thus, new models need not be developed for variations in processing types but the extant model is flexible and can be altered for different situations.

The effect of formation processes on the preservation and distribution of components such as rachii and rachillas is the other issue that needs to be addressed. The distribution of the rachillas and rachii between sieves of different sizes (sieve A, sieve B, sieve C) is noted as an important distinguishing characteristic in certain models. However, questions could be raised regarding their relevance for the interpretation of archaeological assemblages. Formation processes (specifically carbonization through burning) might alter the frequencies of different sized components. For example, sieve A size components might be broken down into sieve B and C, and so on. Therefore, the use of sieve sizes as a parameter in the models might not always be practical given the nature of the particular archaeological assemblage.

Charring Experiment

To address this issue, an experiment was conducted to determine the survival of the rachillas and rachii upon burning/charring. Rachii and rachillas of Panicum miliare, Setaria tomentosa, Sorghum bicolor and Pennisetum typhoides were charred in the laboratory ovens at high (450° C), medium (300° C) and low (150° C) temperatures. The rachii and rachillas of the three different sieve sizes were charred separately, and the different sized rachii and rachillas were charred in three distinct contexts (with sand in earthenware, without sand in earthenware and without sand in aluminum foil). This latter portion of the experiment was done to facilitate variations in charring contexts. After charring was completed, the different sieve size components were examined for breakage and alteration. The results revealed that size transformations did not occur in significant amounts, regardless of the context in which the charring of the rachii and rachillas occurred. However, the main alteration occurred when charring at very high temperatures (over 450° C) which resulted in some sieve A components breaking down to sieve B sizes. The results of the burning experiment suggest that the integrity of the sieve sizes is a potentially viable archaeological criterion. Therefore, variations of components between sieve sizes can assist in the discrimination of products and byproducts of processing stages.

The question of the survival of the different types of Panicum miliare rachillas (without spikelets, with less than 50% spikelets and with more than 50% spikelets) is similar to the discussion of the survival of different sized rachillas and rachii. The archaeological relevance of such a detailed classification of the rachillas could be questioned, and to address this question charring experiments were also done on the three different types of Panicum miliare rachillas. The charring experiment involved testing the survival of the rachillas at different temperatures (high, medium, low) and in different mediums (with sand in earthenware, without sand in earthenware, only in

aluminum foil). After charring was completed, the three rachillas categories were examined for breakage and alteration.

The results revealed that transformations occurred at the high temperatures for the rachillas with spikelets. The rachillas with more than 50% spikelets were most affected since they lost enough spikelets in the burning experiment that they had to be reclassified into the less than 50% spikelets group. The rachillas with less than 50% spikelets were affected minimally, while the rachillas without spikelets were not affected at all. Certainly two distinct groups of components, rachillas with spikelets and rachillas without spikelets could still be distinguished. Thus, the burning experiment reveals that although the integrity of the rachillas with more than 50% spikelets tends to be affected at high temperatures, frequently variations between rachillas with and without spikelets can assist in the discrimination of the products and byproducts of the processing stages.

The survival of the different components of various sizes is also dependent on other processes unrelated to carbonization. The survival and preservation levels of organic material varies depending on the environmental context and the type of sediment in which it occurs. Although these processes cannot be changed, the archaeologist and archaeobotanist can exercise control when excavating organic rich deposits. Careful and cautious excavations are critical for the recovery of fragile plant remains, and the excavator's knowledge of the physical appearance of archaeobotanical remains in sediments is crucial for successful recovery. In addition, processing of archaeobotanical remains should be cautious and conservative to reduce the fragmentation and post excavation alteration of the archaeobotanical materials. Without such care the alteration of archaeobotanical remains during excavation and processing will be of an equal magnitude to the modification done by formation processes.

Summary of Ethnographic Modeling

The ethnoarchaeological research presented in this chapter and chapter 4 has established that there are distinct processing methods and pathways when a crop is processed for its grain. The selection of specific processing methods and pathways is dependent on whether the plant is a Type A crop or a Type B crop. The difference between the two types of crops, Type A and Type B lies in the morphology/structure of the plants themselves and this has a direct effect on the type of harvesting method used on the specific type of plant.

Type A crop plants such as Pennisetum typhoides and Sorghum bicolor have thick stems/stalks and only a limited number (1-3) of crop plant stalks to be cut at a time. Additionally, the inflorescence heads of these crop plants are large distinct panicles which can be harvested individually. Type A crop plant, therefore, can be harvested in two distinct ways: by cutting off only the inflorescence heads and processing them for grain (leaving the stalks in the field), or by cutting 1-3 plants at a time at the base of the plants and then processing them for grain. In this latter method, weed plants are included into the processing pathway, though there could be some selection against them during the cutting itself given the small number of plants selected to cut at one time.

Type B crop plants, such as Panicum miliare and Setaria tomentosa, are harvested in a type B method. The panicle inflorescence of these crops are not as large and distinct as those of Type A crops, and they cannot be singly cut from the plant efficiently. The stalks/stems of these plants are not thick, and a number of plants can be held and cut at the base when harvesting. This is the only method of harvest for Type B crops, and given the nature of the cutting and the crop plants, weeds are included into the harvest, and selection against them during the harvest is not possible. This expected inclusion of weeds during harvest is markedly different from the typical Type I method

harvest of type A crops where weeds are often excluded.

Using the crop processing studies of Sorghum bicolor and Pennisetum typhoides, models were developed for Type A crop processing (see Figures 5-8 and 5-9). The key aspect of the type A crop processing model is that the method of harvest has a distinct effect on the successive processing stages in terms of the compositions of different products and byproducts. The first method, involving only the cutting of the panicle heads, results in a 'clean' harvest where weeds, stalks and straw are entirely excluded from the harvested material. The rest of the plant (the stalks) is harvested subsequently depending on availability of manpower, its need as fodder and the schedule for sowing of the next crop.

In the second method of harvest, when a Type A crop is harvested by cutting at the base of the plant (similar to a Type II harvest), weeds, stalks and straw are included in the harvested materials, and thus need to be processed out in the various stages of the pathway. The harvesting cut may occur either at the very base of the plants (leaving a very small stub which could be removed through ploughing), or the cut could occur up about 1/4 the height of the plant, leaving a longer stubble in the field for cattle to graze. These two cutting variants differentially include low lying weed species in the harvest, but since no other differences exist, they are classified together under one method.

Often when type A crops are harvested in a type B method, they are dried on the threshing floor and occasionally the stalks are separated by cutting them off and directing feeding them to the animals. In such situations, the bulk of the material to be processed is removed, leaving the grain bearing heads and most of the weeds on the threshing floor. This method of processing still creates a very distinctive assemblage in contrast to when a Type A crop is harvested in a Type I method.

I propose that for archaeological applications the most relevant harvest method

for a type A crop is the type B harvest method, when crop plants are cut at the base, thus incorporating the weeds. The thick stems and large sized panicles of Type A crops are probably related to the 20th century genetic alterations to facilitate greater yields of both grain for human food and stalks/straw for fodder usage. These hybrid varieties need a Type I method of harvest, but it is plausible that the ancient varieties might have had thinner stalks and smaller panicles much like the Type B crops. In the absence of genetic information for the ancient strains, it is not possible to comment further on this hypothesis, but it is important to be aware of both possibilities, harvest of Type A crop in Type I method and type B method when conducting archaeological research.

Using similar ethnographic crop processing studies of Panicum miliare and Setaria tomentosa, two models were developed for Type B crop processing (see Figures 5-9 and 5-11). Since Type B crops are always harvested in the Type II method, a key aspect is that there are no variations in the processing of these crops due to harvesting. One parameter, however, that could have a significant affect on the patterning of the crop product and byproduct compositions is whether weeds are present in the fields or not. The two models include processing a type B crop associated with weeds and a type B crop without associated weeds. In the absence of weeds, other plant parts (such as rachillas) can be used as discriminating variables to assist in identifying processing stages products and byproducts.

In addition to the relationships between harvesting methods and type of crops, differences in successive processing was noted for the different crops, specifically with respect to the winnowing and pounding processing stages. Of particular importance is that the winnowing method selected is dependent on the size of the crop grain. Small grained crops are not winnowed by wind, but rather they are winnowed by shaking and this reduces the loss of grain during processing. Crops of larger sized grains witness both winnowing by wind and by shaking. In this study, the Type A crops Sorghum

bicolor and Pennisetum typhoides are both larger sized grain crops, while the Type B crops of Panicum miliare and Setaria tomentosa are the smaller sized grain crops. Although this classification is convenient for this study, not all Type A crops have larger sized grain and not all Type B crops have small sized grain.

Pounding is most often done to dehull, glumed crop grains while grinding is done to convert grain into flour. In this study, pounding was an important stage for the type B crops Panicum miliare and Setaria tomentosa processing, which are both glumed (like glume wheats). However, the type A crops Sorghum bicolor and Pennisetum typhoides are free threshing (similar to naked wheats), and do not need dehulling before consumption. Therefore, pounding is not an important stage for these type A crops. When pounding is a processing stage for Sorghum bicolor and Pennisetum typhoides it mainly functions to complete the removal of husk from grain that did not occur during threshing dehusking (i.e., removal of the seed grain from the spikelet).

There are several general implications of these models that need to be emphasized. Each of these inferences relate to the patterning and distribution of the different components up the processing pathway. They include:

1. No one variable can be used as a discriminating variable, but a combination of components is needed and is much more reliable.

2. Different processing activities create distinct assemblages. For example, winnowing by wind mostly cleans out lighter materials such as straw, chaff and lighter weeds, while winnowing by shaking is more directed and depends on what the processor wants to select out (specifically crop tail grain and heavier weeds). Sieving, on the other hand, is very specific in processing out rachillas, rachii and large seeds (which are infected and bloated).

3. Larger sized components are cleaned out in the early stages while

smaller sized components are cleaned out in the later stages.

4. The smaller the crop grain, higher the frequencies of weeds in the later winnowing by shaking products. Additionally, the larger the prime grain, the fewer the number of weeds in the later winnowing products. It is a matter of efficiency in cleaning and selecting against items that are not the size of the prime grain. The greater the differences in size between the prime grain and the weeds, the more efficient is cleaning in the initial winnowings by shaking.

5. The main cleaning of the prime crop grain (versus tail grain) occurs in the later stages. This pattern is very significant for archaeological discovery and survival into the archaeological record, since the later stages significantly occur in home bases.

6. Weeds seeds are strong discriminating variables, but in their absence, rachillas can be used (as it was done for Panicum miliare processing model).

7. The probability of the different components entering the archaeological record is based on several factors. The important ones considered in this study were fodder usage, storage index, exposure to fire and incorporation into dung.

8. A processor need not have to select only for one crop grain. As shown in the study of Setaria tomentosa, processing can accommodate selection for two crop grains within one sample (Setaria tomentosa and Sorghum bicolor).

9. Decision-making plays an important role in the structure of the processing pathway. This is particularly noteworthy in terms of determining when a byproduct has too much crop grain and needs to be processed further along another parallel pathway, or when a byproduct becomes immediate fodder or stored fodder. The decision making is based on experience of the processor, ethnic/sociocultural behaviors, and other limiting factors such as economic situations and workpower.

In addition to developing models for the processing of the different types of

millets (type A and type B), this research project also proposed to model variations in crop processing when crops are cultivated for three purposes; for only food, for food and fodder or for only fodder. Significant differences in processing were observed for each of these three situations, and they varied depending on the crop type (type A or type B). These differences have measurable effects on the compositions of the products and byproducts of the different stages in the processing pathway (these differences were discussed earlier in this chapter). The differences in processing of a type A crop when cultivated for the three purposes will be briefly summarized, and then the differences in processing of type B crop when cultivated for the same three purposes is examined.

In the rare cases when a Type A crop is only cultivated for food, the harvest method involves only the cutting of the inflorescence heads. This results in a 'clean' harvest with no weeds, straw, stalks (as discussed earlier). The focus of the cultivation and processing is only on the crop grain, therefore the harvest and processing only includes the panicle heads. The resulting compositions of the processing stages products and byproducts are very distinctive, and primarily characterized by an absence of weeds, straw and stalks. There is minimal concern for the stalks left in the field, and often they are left there for relatively long periods of time since they are not used as fodder. The fields are then cleaned before the next sowing. The effort involved in the harvest is moderate in comparison to when the crop is cultivated for the other two purposes.

When a Type A millet is cultivated both for food for humans and fodder for animals, then the harvest can be done in a method similar to Type II method, with the plants cut at the base. When a crop (Type A or B) is cultivated for both human food and animal fodder, the crop grain are used as the human food and the rest of the plant is used as fodder. The focus of the processing is still on retrieval of the crop grain for

human consumption, but the rest of the plant (i.e., the stalks) is efficiently extracted for use as fodder utilizing the byproducts of the various stages. This is the most intensive processing in terms of effort invested when compared to the other two methods of processing (only for food or fodder). It is important to note that weeding is done in both cases when crops are cultivated for food and fodder, and for food only.

When a Type A crop is cultivated for only fodder, in most cases it is not allowed to seed; that is, it is harvested when green. Harvest is by a type B method with the crop plants cut at the base incorporating all the weeds growing in the vicinity. Weeding is absent when a crop is cultivated for fodder. When a crop is cultivated only as a fodder, it is not processed further than harvesting, since the best cattle fodder is green fodder (only pregnant cows are given grain).

Thus, the differences in processing of a Type A crop when it is cultivated for only food (in rare cases), for food and fodder (most common), and only for fodder only, lie in the harvest methods and times. The different harvest methods have obvious, measurable effects on the composition of the products and byproducts of the various stages. The harvest time and whether a crop is processed or not (as is the case when a crop is cultivated only for fodder) has a direct effect on whether the cultivation is detectable archaeologically.

Differences in processing when type B crop is cultivated for the three purposes were discerned, but the differences were not as distinct as those for type A crops. The main difference lies in the harvest times, and as discussed earlier when a crop is cultivated for fodder only it is not processed after harvesting.

When a Type B crop is cultivated only for food, or for food and fodder there is no significant difference in the processing except that in the former case byproducts are not fed as fodder to animals. There is no distinctive difference in the processing or harvest method between the two cases. It is, however, probable that the crop might be

harvested slightly greener when the use is as fodder. This is important since it affects the compositions of the crop products and byproducts in the processing stages, particularly in terms of the frequencies of the rachillas. The greener the crop at harvest, the fewer rachillas in the crop products and byproducts (refer to the differences between ROC and SOC plots in the study of 'Opportunistic' cultivation of Panicum miliare). It could also be deduced that there would be more headed weeds in early harvests (when crop is still partially green) since the weeds are also immature and would not thresh free as well as when they were matured and dry. Thus, these two patterns could be used to determine whether a crop was cultivated and processed only for human food or for food and fodder.

When a Type B crop is cultivated only for fodder, then it is harvested green and not allowed to seed (as is the case for type A crops). It is also not processed beyond harvesting. Thus, such cultivation is very unlikely to be detected archaeologically, and parallel lines of evidence are needed to determine such cultivation of plants for fodder.

CONCLUSIONS

This chapter has isolated the variables which distinguish the different crop processing stages products and byproducts, and presented ethnographic models for archaeological interpretations. These models complement and extend the ethnographic models presented by Hillman (1981, 1984), Jones et. al. (1986) and Jones (1988, 1987) in that they focus on different crops and different processing methods. Hillman (1981, 1984) and Jones (1988, 1987), suggest that alternative processing methods are minimal, and therefore they lose the opportunity to discuss technological style in crop processing. For example, the necessary separation of grain from weed seeds and chaff is a

processing stage with alternative solutions. The Near Eastern method predominantly involves sieving for this separation (Hillman 1984). As demonstrated in this study, however, a flat basket is tapped or shaken in South Asia, while in Australia a wooden dish is rocked (Cane 1989). This study has also demonstrated that the specific technique of winnowing (by shaking) varies significantly from the technique of winnowing by wind (which is the only winnowing method in the Near East). Furthermore, it has been demonstrated that the products and byproducts of winnowing by shaking are distinct from those of winnowing by wind.

Since these methods of separation produce statistically distinct product and by-product assemblages, it would be interesting to trace the development and adoption of different methodologies. Such research would be of particular interest in areas where both methods are known, yet one is specifically chosen, perhaps as a element of group identity. Jones (1984) has suggested that in order to identify activity areas, the functions of building etc., it is more important to know the processing stage rather than the processing method used. I argue that this approach has an important shortcoming relating to aspects of ethnic group identity and socio-cultural behavioral practices related to adoption of processing methods. There is obvious selection of processing methods and pathways based on several factors as discussed in this chapter, but ethnic and socio-cultural identity also play an important role. Therefore, whether it is a matter of different crops needing different processing, or socio-cultural decision making and determination, these differences could have wide ramifications in the study of ancient farming practices. This research has noted that different crops need different processing, but decision making on the specifics of the processing is identified as an important aspect of crop processing in South Asia.

Identification of reaping heights from charred remains has been discussed by van Zeist (1968), Jones (1979), Hillman (1973, 1981) and Reynolds (1981). Jones

(1979), Hillman (1973, 1981), Reynolds (1981) and van Zeist (1968) addressed reaping (which could be argued as being identical to Type II method of harvesting in this study) and uprooting (which was not observed in this study). However millets were not considered in their research, nor were variation in the harvesting methods addressed. This study is an important new contribution due to its focus on millets and differentiation of crops on the basis of the harvest style. Moreover, a major contribution of this study is the observation that distinctions between harvesting styles (such as Type I method and Type II method) has a direct effect on the compositions of the successive products and byproducts down the processing pathway.

CHAPTER 6

PALEOETHNOBOTANICAL RESEARCH AT ORIYO TIMBO AND BABAR KOT

INTRODUCTION

The study of plant remains from archaeological sites provides information for the interpretation of changing patterns and continuing trends of the past environment, subsistence and economy. This chapter presents the paleoethnobotanical research at two Gujarat Late Harappan sites, Oriyo Timbo and Babar Kot in Gujarat, India. The objectives of the archaeobotanical research at these two sites include the description and interpretation of the archaeobotanical materials recovered, and presentation of a working model for the economic role of millets in the subsistence system at each site and for the region as a whole. Gaining an understanding of the nature of the subsistence economy, and elucidating spatial and temporal variation in the plant materials at each site are important themes of this chapter.

The structure of this chapter consists of first an archaeological background of the two sites, and then the archaeobotanical procedures followed for each site, including discussions on sampling, recovery, analysis and identification. The archaeobotanical results from Oriyo Timbo and then Babar Kot will be discussed. The results of this chapter will then be used in chapter 7 to evaluate the ethnographic models presented in chapter 5.

ARCHAEOLOGICAL BACKGROUND OF ORIYO TIMBO AND BABAR KOT

The archaeobotanical field investigations at Oriyo Timbo and Babar Kot were conducted by the author as a part of larger excavation projects. Both the sites are located in the modern state of Gujarat in northwest India (Figure 6-1), and were excavated through collaboration between the Gujarat State Department of Archaeology

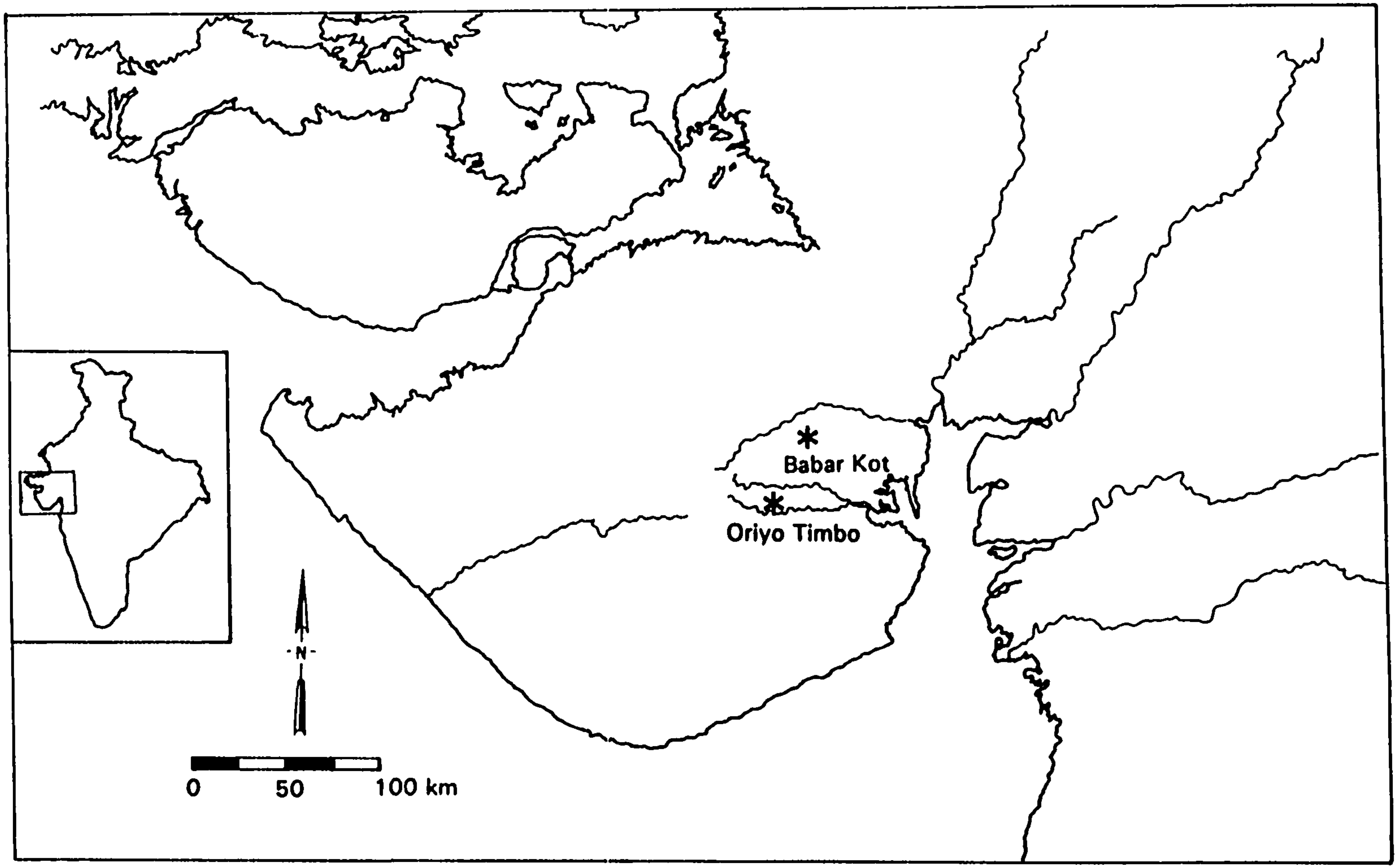


Figure 6-1. Map Showing the Sites of Oriyo Timbo and Babar Kot

and the University of Pennsylvania, under the direction of Dr. Gregory L. Possehl. Oriyo Timbo was first excavated in 1981-82 by the joint team (Rissman and Chitalwala 1990), and a subsequent second season of excavations took place in 1989-90. The archaeobotanical research relevant to this dissertation was conducted during this second season at Oriyo Timbo (1989-90). The site of Babar Kot was excavated in 1990-91 by a similar joint team collaboration between the Gujarat State Department of Archaeology and the University of Pennsylvania, under the direction of Dr. Gregory L. Possehl.

Oriyo Timbo

The Late Harappan site of Oriyo Timbo has Lustrous Red Ware ceramics and radiocarbon dates indicating occupation around 1900-1800 B.C (Chitalwala and Rissman 1990). Below the Late Harappan occupation is a microlithic occupation which was not well defined in the first season of excavations and not explored at all in the second season. Oriyo Timbo is located inland on a cultivated plain between two rivers. The Ghelo river is situated 8 km north of the site and the Khalubhar river lies 4 km south (Possehl 1980:38). The site itself (a low mound, 150 X 160 meters) sits on the banks of a seasonal tributary of the Khalubhar river.

During the first season of excavations at the site, three excavation operations were conducted; the eastern, western and central operations (Rissman and Chitalwala 1990: 5-11). The western operation was the most successful, and the excavation units of the second season focussed around this location. The second season of field research at the site took place in 1989-90, and it entailed the excavation of six 5 X 5 m grid units immediately south of the western operation area for the 1981-82 excavations (Rissman and Chitalwala 1990: Figure 1). This specific area was selected since it was close to the most promising location on the site, from which further information on the character of the site could be gained (Possehl 1990). Between the two seasons approximately 3% of

the site was excavated. The main objective of the second season of excavations was to define the nature of the Late Harappan occupation and to test the notion that this was an ephemeral pastoralist camp. The goals of my paleoethnobotanical study were developed from the goals of the project itself and included defining the importance of millets in the subsistence economy of Oriyo Timbo.

In this second season (during which archaeobotanical materials were recovered for this research study), six 5 X 5 meter trenches were excavated. Only two of the five trenches were excavated to sterile sediment. The others were dug down to expose a series of occupational surfaces with associated features (Possehl 1990). All soil (except the disturbed plough zone which was 20-30 cms deep) was screened for artifacts, and in addition large volumes of sediment were floated from all excavated areas for macro-botanical remains. Soil sediments from features were often floated in their entirety. The sample size and collection will be discussed in the subsequent sections of this chapter.

In the course of the excavations in 1989-90, twelve stratigraphic layers and sub-layers which comprised no more than 3 major distinguishable occupations were identified. The depth of the cultural deposits ranged from 120 to 130 cms below the surface. The top 20 to 40 cms of the cultural material below surface was disturbed to varying degrees through agricultural activities. In general there appeared to be considerable artifact movement in the upper deposits (both horizontally and vertically), exemplified by the find of a 19th century coin at a depth of over 50 cms.

The upper layers of the site are associated with the top soil and the plow zone, and are extremely disturbed. These strata (1 and 2), are distinct from stratum 3 which is a series of very compacted soil layers and artifact concentrations. The excavators consider stratum 3 to represent the latest Late Harappan occupation surface at the site. Stratum 4, a softer compacted fill, is distinct from the compacted series of layers in

stratum 5 (5, 5a, 5b). Associated with these layers are high densities of ceramics and features associated with food preparation (i.e., hearths, a tandoor oven and ash pits). Stratum 6, a soft fill, separates the next series of compacted occupation surfaces (6a, 6b, 6c) which have occupation features, ceramics and various artifact concentrations most closely related to Lustrous Red Ware cultural sequence. These Late Harappan surfaces extend down directly onto the sterile soil of stratum 7. Stratigraphically, strata 6a, 6b and 6c are associated with Late Harappan Occupation I, strata 5, 5a and 5b are associated with Late Harappan Occupation II, and Late Harappan Occupation III is represented by stratum 3 (Possehl 1990). The disturbed upper strata and the unexcavated microlithic occupation are not considered further in this study. Additionally, samples from or associated with disturbed contexts such as rodent holes, were not considered for archaeobotanical study. Such contexts were, however, minimal in the second season of excavations at Oriyo Timbo.

The material culture from the site included a variety of ceramic types, majority of which were Lustrous Red Ware. Detailed study of the ceramics is still pending. The significant features at the site included hearths, pits and/or trash pits. Additionally, a tandoor oven was found in Occupation II, its inner walls charred and contained an ashy, charred matrix. The contents of this feature were floated to retrieve archaeobotanical materials. An interesting semi-spherical feature with sides sloping downward toward the center was observed in Occupation III. The central portion contained a compacted floor surface with a diameter of 2 to 3 m. Although a final interpretation has not been offered by the excavators, it is likely that it could be a living surface associated with a temporary structure, and the raised walls represent the perimeters of the dwelling. This hypothesis could be tested through ethnoarchaeological investigations of pastoral camps in the region.

The results from the second season of excavations differ from those of the first

season in a number of ways, but also complement them (Possehl 1990). Lustrous Red Ware was observed throughout the occupation layers, and many strata were identified on the basis of stratigraphy from the previous excavation, thus indicating continuity between the areas excavated. However, the Late Harappan Lustrous Red Ware occupation uncovered in the second season was lower than previously recognized, and the earlier microlithic occupation found in the first season of excavations was not present in the area excavated during the second season (Possehl 1990). Based on the second season of excavations, the excavators propose that there are three distinct Lustrous Red Ware occupations, each associated with a series of compacted surfaces with features and concentrations of artifacts resting upon them. Softer, less compacted soil of strata 4 and 6 represent the general deposits between the three occupation layers.

The importance of the site lies in its location between two rivers, and this factor was in the first season of research by Rissman and Chitalwala (1990) and an earlier survey by Possehl (1980). There are numerous Harappan sites along the two rivers (Possehl 1980), but of a sample of 36 Harappan sites, only Oriyo Timbo is not located within 200 m of the Ghelo or Khalubhar rivers. Possehl (1980) has suggested that Harappan site locations near the river bank were designed to take advantage of a strip of land kept free of dense vegetation by periodic flooding, thus eliminating the need to clear land for cultivation. Possehl argues that the riverside location of the Harappan sites was designed to facilitate cultivation. The location of Oriyo Timbo is intriguing since it obviously does not optimize this situation, therefore suggesting that agriculture might not have been a critical subsistence component.

Rissman and Chitalwala (1990), through their 1981-82 season of investigations at Oriyo Timbo have suggested that Oriyo Timbo was not a self-contained permanent settlement. Instead it was occupied only on a seasonal basis, with the Oriyo inhabitants

living elsewhere at other times of the year. They concluded that Oriyo was an ephemeral site with hearths, hoof prints, and a possible windbreak tent, all suggestive of a transient habitation. No permanent architectural features were found, and lastly the very high density of herd (cattle) animals bones marked the distinctive character of the site.

Rissman (1986) investigated these indications of a non-agricultural, non-sedentary Late Harappan site through analysis of annual rings in cattle teeth to determine the times of years when they were slaughtered. The fauna from Oriyo Timbo exhibited a predominant season of death between March and July, suggesting that the livestock, and therefore perhaps humans did not occupy the site year round. This interpretation fits well with the ephemeral nature of the site, and its location on the banks of a seasonal tributary. However, the presence of cultivated millets (Setaria spp, Eleucine spp, Panicum spp) at the site confuse the picture (Rissman & Chitalwala 1990, Wagner 1982). Rissman and Chitalwala (1990) argue that the pastoralists relied upon grains as well as animal products, and that there were presumably contemporaneous agricultural villages situated on the banks of the rivers in the general region with which the Oriyo habitants could have interacted. No investigations were conducted on whether the millets recovered at the site were cultivated there or brought in from elsewhere, and this remained a key research question. Rissman and Chitalwala, however, argued that when the data in their entirety are considered they support the interpretation that Oriyo Timbo was a dry season cattle camp that played an important role in the pastoral economy of eastern Saurashtra.

My archaeobotanical research conducted during the second season of fieldwork was thus designed to help elucidate the character of Oriyo Timbo. Specifically, the research was designed to determine whether crops were cultivated at the site by the occupants or brought to the site from elsewhere, which can be done through the

identification of lower and/or higher crop processing stages (as presented in chapter 5 and elaborated in chapter 7).

Babar Kot

Babar Kot is set on the banks of a small seasonal river in the semi arid portion of Saurashtra, and a variety of crops are currently cultivated in the immediate environs (Figure 6-1). The site is a pronounced mound (190 X 140 m), about 2.7 hectares in area and 2.5 m high (Possehl & Raval, 1991). The present day contours of the site suggest that it was surrounded by a fortification wall, and this was revealed by the excavations.

The excavations at the site were designed to address four broad issues (Possehl & Raval 1991): chronology and ceramic styles, organization of the settlement, non-subsistence economy, and subsistence economy. The goals of my paleoethnobotanical study developed from the fourth goal of the project, and included description and interpretation of the Babar Kot archaeobotanical remains and presentation of a working model for the economic role of millets in the subsistence system at Babar Kot and its significance to the region.

There were two excavation areas at the site; the main excavation area on the sloping southwestern quadrant of the site; and a second excavation area on the mound 50 m north of the main excavation area. This latter mound excavation consisted of a 5 X 10 meter trench (Possehl and Raval 1991). The main excavation area is referred to as the slope area, while the 5 X 10 meter trench on the mound is referred to as the mound area. A total area of 28 5 X 5 meter excavation trenches were opened in the two areas. The main excavation area explored the fortification wall and the horizontal exposure of the habitation area. Approximately 3% of the site was excavated during the first season

at Babar Kot.

The basic stratigraphy was similar in both areas. The top stratum had remains of early historic Red Polished Ware to medieval occupations. These upper deposits (divided into strata 1 and 2) rest directly upon the Late Harappan occupation (Possehl and Raval 1991). The stratigraphic break was very well defined by the color and texture of the soil, thus the two principal occupations (Early Medieval and Late Harappan) are clearly demarcated. The excavators propose that the early historic period occupants certainly leveled the top portion of the Late Harappan site carefully before building their settlement. The Late Harappan ceramics from Babar Kot suggest that the site is Late Harappan (Rangpur Phase), equivalent to Rojdi B & C (2200 - 1700 B.C). Detailed study of the Babar Kot ceramics is pending.

In the main excavation area, there were two significant architectural finds: the fortification wall and an area with wall foundations. These wall foundations were of two types, stone and very clean, well prepared black clay ("kali mate"). The full nature of the fortification is not understood at this point, but evidence suggests that it dates to the initial occupation of Babar Kot (Possehl and Raval 1991).

The trench on top of the mound, which has the greatest depth of cultural deposits as well as the least disturbance, reveals sterile soil at a depth of 3.25 m below the present ground surface. It consists of 11 different stratigraphic layers which have been divided into three building phases (Possehl and Raval 1991). The building phases are numbered with Roman numerals from bottom to top with the bottom being the first phase of occupation. The order of the stratigraphic layers is reversed, with the numbering top to bottom and the top being the most recent stratum. Therefore, the early historic occupation, phase III is associated with strata 1 and 2. Phases II and I are interpreted as Late Harappan based on the presence of Harappan ceramics. Phase II is comprised of strata 3, 4, 4a, 5 and 5b, while Phase I (the earliest building phase)

includes strata 7 and 8.

For the purpose of the archaeobotanical analysis the building phases and strata are organized in order to compare and contrast the three different Late Harappan occupations. Occupation I is the earliest and is associated with the strata 9 and 10. It has no buildings and is considered to be the initial occupation. Occupation II is associated with strata 6, 7 and 8, and corresponds to the building phase I. Occupation III consists of strata 3, 4, 4a, 4b, 5 and 5a, and is associated with building phase II. The last occupation (building phase III) was not studied for this project, since it is historic in age. Therefore, the relationship:

Occupation IV	Building phase III (Early historic)
Occupation III	Building phase II (Late Harappan)
Occupation II	Building phase I (Late Harappan)
Occupation I	No buildings (Late Harappan)

Occupation III (the middle building phase, phase II) is the most extensive and on the mound is represented by a well preserved stone wall dividing the excavated area into two rooms (Possehl and Raval 1991). The cultural material associated with this architectural phase is "Rojdi C" in style. The corner of one room in this phase has remnants of a hearth or cooking area. A feature related to storage was recovered from the corner of another room. Soil samples were taken from these contexts to retrieve organic remains.

Occupation II (the earliest architectural phase) has fewer features and it is difficult to speculate much about the buildings associated with this phase (Possehl and Raval 1991). The associated cultural remains differ slightly from the Occupation III

materials.

The excavators argue that the mound trench indicates the presence of a Late Harappan occupation with material similar to "Rojdi C", and two building phases. Cultural materials such as grinding stones, and the archaeobotanical materials recovered through flotation suggest that there is evidence of food preparation at the site. The excavators have not determined the full character of the site but it is clear that it is not an ephemeral site like Oriyo Timbo. The substantial architecture and associated cultural material, suggest that Babar Kot represents a small settlement whose inhabitants may have cultivated crops, with millet cultivation as one aspect of their subsistence economy. The archaeobotanical investigations at Babar Kot focus on addressing the economic importance of millet cultivation at the site.

Summary

The sites of Oriyo Timbo and Babar Kot, present two very different ecological and archaeological contexts to study the role of millet cultivation in the Late Harappan of Gujarat. Oriyo Timbo appears to represent a pastoral cattle camp where the focus of the subsistence economy is animal husbandry, while Babar Kot represents a permanent settlement with substantial architecture and extended period of occupation. Subsistence agriculture supplemented by other resources were no doubt important elements of the latter. These two settlements are used in this study as examples of variations in Late Harappan subsistence systems and the differing role of millets in their subsistence economy. Of particular relevance are questions such as were millets cultivated, were the millet grains exchanged with agriculturalists, or were they grown in both systems but in different degrees of intensity. The archaeobotanical investigations in conjunction with the ethnographic modeling facilitate the investigations of these issues.

ARCHAEOBOTANICAL METHODS AND SAMPLING PROCEDURES

The archaeobotanical methodology employed in this project emphasizes the importance of intensive sampling and the use of an efficient plant recovery system to help provide a richer understanding of past subsistence economies. Sampling and macro-botanical recovery methods were held constant in the investigations at Oriyo Timbo and Babar Kot. This was done to ascertain comparability between the two data sets for patterns of distribution, occurrence and ubiquity of the archaeological plant remains. This is necessary to address issues related to variation and similarity in millet cultivation at the two sites. This section presents the sampling, recovery, identification and analysis procedures employed in the archaeobotanical studies at the sites of Oriyo Timbo and Babar Kot.

Sampling

Achieving strong contextual information through intensive sampling is a necessary goal of paleoethnobotany in order to facilitate a thorough understanding of the variability in activities related to food procurement, processing, consumption and disposal (Hastorf and Popper 1988).

A highly representative archaeobotanical assemblage would include all the plant species actually in use at a site along with some indication of the relative importance of the remains in antiquity. Adequate sampling from a sufficiently large number of contexts is imperative to achieve such an assemblage. Therefore, to ensure adequate plant retrieval from the site, detailed sampling was employed at both the sites.

At Oriyo Timbo, 3,139 liters of archaeological sediment from 247 samples were processed, with a minimum volume of 10 liters per sample unless there was a defined feature. Similarly a total of over 200 soil samples representing over 3,000 litres were

floated for archaeobotanical remains at Babar Kot. The sample contexts from the two sites include hearths, ovens, compact living floors, dumps, pits and fill areas. Sediment samples from deposits which did not have any features were also taken for flotation. Essentially, float samples were collected as often as possible. As noted, such sampling methods are necessary for the successful recovery and identification of macro-assemblages and localized associations related to different economic activities such as plant processing, consumption and disposal. Given this rigorous sampling it is asserted that the sediment samples floated for archaeobotanical remains are very representative of the excavated areas of the two sites.

Recovery

The water flotation system used for plant recovery comprised of an oil tank modified to a S.M.A.P-type machine (called Piyush One) used previously at the sites of Rojdi and Oriyo Timbo (Wagner 1985, Weber 1989). Recovery tests run with charred poppy seeds indicate that 86-97% of floating seeds were recovered. A wooden box to catch the light fraction was constructed with no top and a bottom covered with #30 mesh (0.6 mm^2 opening) brass screen which is nailed on. Placed on the top of the box was a 12" x 12" rectangle piece of cloth. Polyester cheese cloth with a sizing of 80 x 10 threads per square inch was used. These pieces of cloth were attached to the top of the light fraction box by brass thumb-tacks.

Special emphasis was made on having standardized control on the volume of sediment processed. A standard of 10 liters was taken for each float sample, unless it from was a feature, feature fill or a floor. In order to ensure a strong good yield of seeds specific to contexts, every feature or feature fill was processed if possible. A bucket which was marked and recorded was used for this process. When a sample was over 10 liters, it was spilt up and processed in lots of 10 liters, and later after drying

the respective heavy and light fractions were combined. This strategy was adopted to facilitate a consistent recovery process. When the samples were clayey and clumpy, they were preprocessed before flotation. Typically these samples were hearth features which were sun baked after exposure. The clumps were broken gently by hand before flotation. To avoid losses due to chemical reactions, baking soda or any other equivalents were not used to aid in this process.

The system was run for 15 minutes every morning before any samples were processed to wash out the tank and avoid contamination both from previous samples processed and exterior elements. The heavy fraction basket was also washed out thoroughly after every sample, to ensure minimal contamination. The tank bottom, where the washed sediment settles, was cleaned out when the water started getting turbid. The water supply was maintained as continuous as possible, given the constraints of the field situation. It usually took approximately 20 minutes to float 10 liters of sediment, which also included note taking and label making. The sediments were described whenever appropriate. In general, the upper strata from both sites were impregnated with many rootlets and root hairs. The lower strata also had them, but in lesser quantities. On the average, about 70 liters of sediment were processed before the tank had to be cleaned out.

For each flotation sample processed, the context was noted and volume measured before it was deposited into the heavy fraction screen in the flotation tank. The outflowing light fraction was caught continuously in the box, while the sediment was agitated gently by hand to help break the soil lumps. Once the sample was processed, the heavy fraction box was lifted and emptied out to dry on labeled newspapers laid in the sun. The light fraction bag was tagged and hung on a clothesline to dry. The heavy fraction bucket, the measuring bucket and the walls of the tank were

washed out thoroughly before the next sample was processed.

After the heavy fractions were dry, they were sieved through geological sieves with 4.0 mm, 2.0 mm and .4 mm openings. Contents from each of these screens were sorted and recorded. The plant remains were combined with the corresponding light fraction and stored in plastic vials. Careful attention was given to keeping the contamination to a minimum at every step. All the lithics, bones, pottery and other artifacts were recorded and bagged separately to be sent to the appropriate analysis stations. The light fractions were emptied out of the cheese cloths and stored in plastic vials for analysis at a later date.

As with most if not all plant recovery systems, the major concern during flotation was to minimize loss, contamination and damage to the plant remains. The Oriyo Timbo (1989-90) and Babar Kot (1990-91) recovery methods minimized these concerns by thorough cleaning of the flotation tank, heavy fraction screen and the light fraction box. The use of a continuous water supply automatically controlled for much of this.

Identification and Analysis

The first step in the analysis was to scan the light fraction sample for seeds using a binocular dissecting microscope. A comparative collection compiled in India by the author, Dr. Vishnu-Mittre and Dr. Steve Weber was used for seed identification.

During the sorting process, charcoal and carbonized seeds were separated from the light fraction samples by scanning under a light binocular dissecting microscope at 10X, 20X and 40X. The volumes of the light fractions and charcoal were measured and recorded. Observations on the presence of fresh organic materials and possible signs of disturbance such as insects were recorded. Both carbonized and uncarbonized seeds were recovered, however in this study a conservative stance is adopted and only the

carbonized seeds are in the analysis. Since organic preservation is poor at the sites, the uncarbonized seeds are interpreted as later intrusives and not of Late Harappan context, and their exclusion increases the reliability of the assemblages. The only way to ascertain the age of these uncarbonized seeds would be through accelerator dating. The condition of the carbonized seeds varies from very good preservation to badly charred distortion. Drawings were made of the primary seed types to facilitate accurate identification.

Select samples were analyzed in greater detail from both sites. The selection of samples for detailed analysis was based on several criteria, including strong Late Harappan context, minimal disturbance associated with the samples and preference for samples from household activity contexts.

In order to more accurately examine patterns in the data, and to avoid any biases due to differences in volumes of sediment floated (Popper 1988:60), certain quantification methods are needed. For the study of archaeobotanical remains of Oriyo Timbo and Babar Kot, two specific quantification methods are chosen which involve the use of ratios, densities and percentages. Densities are generally used as a measure for understanding depositional and perservational variability, and it is one of the most basic ratios used by paleoethnobotanists (Miller 1988:2). The basic assumption is that if everything is equal, the larger the volume of sediment floated more plant remains will be extracted. In other words, the higher the density, the more intense the activities involving the particular plant and fire (Pearsall 1983: 129). Therefore, with a good control and understanding of the context, the use of specific plants by site inhabitants can be reconstructed. The second quantification method used in this dissertation is that of percentage which refers to the relative abundance of a specific taxon in an assemblage. Paleoethnobotanists used it as a indicator of floral importance (Miksicek

1983), or to compare different preservation contexts, or to detect replacement of one category by another (Miller 1988), or as a magnitude of past accidents (Minnis 1978). In this dissertation, both densities and percentages are used for robust paleoethnobotanical reconstruction.

The absolute counts of carbonized seeds from the two sites were converted into standardized densities: number of seeds per 1,000 litres of sediment for Oriyo Timbo, and number of seeds per 100 liters of sediment for Babar Kot. This standardization allows the data from different trenches and strata to be compared, and is the basis of most discussion. The standardized volume sizes of 100 and 1,000 litres was chosen to ensure that the more subtle patterns in the data are easily deciphered and revealed. The standardization for the Oriyo Timbo data was for a higher volume (1,000 litres) because of the lower recovery as compared to Babar Kot.

ORIYO TIMBO ARCHAEOBOTANICAL RESULTS AND DISCUSSION

The goal of the archaeobotanical research at the site was to elucidate the role of millets in the subsistence system, and thus evaluate the previous characterization of Oriyo Timbo as an ephemeral site where summer crops were not being cultivated by the inhabitants. This section includes description and interpretation of the Oriyo Timbo archaeobotanical plant remains. Detailed species discussions are presented, followed by examination of spatial, stratigraphic and contextual trends. Finally a working model for the economic role of millets in the subsistence system at Oriyo Timbo is presented in the summary.

During this second season of excavations at Oriyo Timbo (1989-90), carbonized and uncarbonized plant remains were retrieved from 247 samples comprising of 3,139 liters of unscreened dirt from 6 trenches. The majority of the recorded seeds were scattered in the archaeological matrix of the site, although some samples came from

quite distinguishable contexts such as ashy pits and features. The plant remains occur in varying frequencies in all the excavated trenches, but significantly higher concentrations exist in 3 of the 6 trenches. Stratigraphically there is patterned variation in the frequencies of carbonized seeds recovered. The strata relating to occupation II have higher frequencies of seeds as compared to Occupation III and I strata.

In the second season of field research at Oriyo Timbo, six 5 X 5m trenches were excavated: S2, S4, S5, S6, S8 and S9. The archaeological context of trench S4 was disturbed and only 2 archaeobotanical samples were analyzed, both of which were sterile. Hence, only archaeobotanical data from the other 5 trenches S2, S5, S6, S8 and S9 are discussed here. In addition, Occupation III represented by stratum 3 is not addressed in this study because of associated disturbance. At Oriyo Timbo, the upper strata show extensive disturbance. Therefore, to avoid any biases in the data due to disturbance, this study considers only the earliest two occupations at the site.

There is strong evidence for the use of summer crops at Oriyo Timbo based on the 1989-90 archaeobotanical results. This includes summer crop plants such as Eleucine coracana, Panicum miliare, Setaria spp and legumes (including Phaseolus mungo and Brassica sp). Weed seeds of Mollugo sp, Urochloa sp, Trianthema sp, Carex sp and Euphorbia sp are also present in relatively high proportions. Whether the crops were cultivated at the site by the occupants or brought onto the site from elsewhere, is an intriguing question, and the archaeobotanical analysis investigates this issue.

Tables 6-1 and 6-2 present the absolute counts and standardized archaeobotanical data by trench. A total of 413 carbonized seeds have been identified, of which 41% are 'millets' (summer crops) and 51% are weeds. Among the millets, Setaria spp. comprises 16% of the total seed assemblage, followed by Eleucine sp.

Table 6-1. Oriyo Timbo: Archaeobotanical Absolute Counts by Trench

DATA	S2	S5	S6	S8	S9	TOTAL
Flot vol (litres)	320	200	404	175	576	1675
LF (ml)	34	10	69	30	80	223
Carbonized Seeds	106	15	139	80	73	413
Eleucine sps	26	0	32	3	11	72
Panicum miliare	18	3	12	1	1	35
Setaria sps (total)	35	0	29	5	5	74
S.italica	20	0	17	2	3	42
S.glauca	0	0	3	0	0	3
S. tomentosa	15	0	9	3	2	29
Unidentifiable millets	0	0	3	2	0	5
Total Carb millets	79	3	76	11	17	186
Phaseolus mungo	9	5	5	0	3	22
Brassica sps	0	0	1	0	0	1
Unidentifiable legumes	0	0	4	1	1	6
Total Legumes	9	5	10	1	4	29
Amaranthus sps (SFH)	1	1	1	0	0	3
Carex sps (SFH)	1	0	11	0	0	12
Chenopodium sps (SFH)	0	0	4	0	0	4
Cyperus sps (SFL)	0	0	0	1	1	2
Dactyloctenium sps (SFL)	0	0	1	0	0	1
Digera sps (SFH)	1	0	0	1	2	4
Digiteria sps (SFH)	2	0	4	0	0	6
Euphorbia sps (SFH)	0	4	2	0	0	6
Mollugo sps (SFH)	4	1	13	62	12	92
Phyllanthus sps (SHH)	0	0	0	0	1	1
Solanum sps (SFH)	1	1	2	1	0	5
Trianthema sps (SFH)	0	0	5	2	4	11
Urochloa sps (SFL)	0	0	10	1	32	43
Total Weeds	10	7	53	68	52	190

SHH = Small Headed Heavy
SFH = Small Free Heavy
SFL = Small Free Light

Table 6-2. Oriyo Timbo: Archaeobotanical Standardized Densities by Trench

Standardized Densities

TRENCH	S2	S5	S6	S8	S9	TOTAL
Sediment Volumn	1000	1000	1000	1000	1000	5000
Carbonized Seeds	331	75	344	457	127	1334
Eleucine sps	81	0	79	17	19	196
Panicum miliare	56	15	30	6	2	109
Setaria sps (Total)	109	0	72	29	9	219
S.italica	63	0	42	11	5	121
S.glauca	0	0	7	0	0	7
S.tomentosa	47	0	22	17	4	90
Unidentifiable millets	0	0	7	11	0	18
Total Carb millets	246	15	188	63	30	542
Phaseolus mungo	28	25	12	0	5	70
Brassica sps	0	0	2	0	0	2
Unidentifiable legume	0	0	10	2	2	14
Total Legumes	28	25	24	2	7	86
Amaranthus sps (SFH)	3	5	3	0	0	11
Carex sps (SFH)	3	0	27	0	0	30
Chenopodium sps (SFH)	0	0	10	0	0	10
Cyperus sps (SFL)	0	0	0	6	2	8
Dactyloctenium sps (SFL)	0	0	2	0	0	2
Digera sps (SFH)	3	0	0	6	4	13
Digiteria sps (SFH)	6	0	10	0	0	16
Euphorbia sps (SFH)	0	20	5	0	0	25
Mollugo sps (SFH)	13	5	32	354	21	425
Phyllanthus sps (SHH)	0	0	0	0	2	2
Solanum sps (SFH)	3	5	5	6	0	19
Trianthema sps (SFH)	0	0	12	11	7	30
Urochloa sps (SFL)	0	0	25	6	56	87
Total Weeds	31	35	131	389	92	678

SFH = Small Free Heavy
SFL = Small Free Light
SHH = Small Headed Heavy

(15%) and Panicum spp. (8%). Legumes constitute 6% of the total assemblage. Among the weeds, Mollugo sp. (32%) comprises the highest percentage. No rachii or other plant parts were recovered.

As compared to the archaeobotanical finds of the first season of excavations at Oriyo Timbo (Wagner 1983), the second season had higher overall recovery rates. The higher recovery rates is due to the larger quantity of sediment processed through flotation, and the use of a more efficient plant recovery system.

Detailed Species Discussion

Eleucine sp..: A total of 72 carbonized Eleucine sp. caryopses were recovered from 4 trenches, with trench S2 and S6 having the highest standardized densities (Table 6-1, 6-2). They are most probably Eleucine coracana. Of these more than 80% were measurable, and the measurements averaged 1.1mm in length, 0.9mm in width and 0.8mm thick. It was consistently noted that during carbonization the sides of the grain were often pulled apart, which spilt the apex open and the interior was exposed. This form of distortion was most frequently noted for Eleucine sp. grains.

Ethnographically, Eleucine coracana seeds are used primarily as human food. They are consumed either cooked like rice, or made into a flour for bread and porridge. The vegetative parts of the plant are valuable as green and dried fodder for animals. The storage of Eleucine coracana is extensive, and in majority of the cases, fresh grain is seldom used as food, but has to be stored for some months before it is utilized. The implications of this practice are significant for archaeological interpretations and modeling, and will be addressed in the next chapter.

Eleucine occurs in highest frequencies in Occupation I strata (Table 6-3). However, more specifically, Eleucine sp. seeds occur in the highest frequencies in stratum 5A of Occupation II, although the densities for Occupation II in general are

Table 6-3. Oriyo Timbo: Archaeobotanical Standardized Densities by Occupation

Standardized Densities

	Fill	Occupation II			Fill	Occupation I			Fill
Sediment Volumn	1000	1000	1000	1000	1000	1000	1000	1000	1000
Stratum	4	5	5A	5B	6	6A	6B	6C	7
Carbonized Seeds	116	220	719	30	297	295	426	0	62
Eleucine sps	22	23	193	0	43	159	125	0	0
Panicum miliare	9	10	140	0	26	0	42	0	0
Setaria sps (Total)	24	27	263	15	35	45	51	0	0
S.italica	9	16	158	15	26	45	10	0	0
S.glauca	0	1	0	0	9	0	10	0	0
S. tomentosa	15	10	105	0	0	0	31	0	0
Unidentifiable millets	3	2	0	0	9	0	21	0	0
Total Carb millets	58	62	596	15	113	204	239	0	0
Phaseolus mungo	6	4	70	0	35	0	10	0	31
Brassica sps	0	0	0	0	0	0	10	0	0
Unidentifiable legumes	0	4	0	0	9	23	0	0	0
Total Legumes	6	8	70	0	44	23	20	0	31
Amaranthus sps (SFH)	3	1	9	0	0	0	0	0	0
Carex sps (SFH)	3	2	0	0	17	0	73	0	0
Chenopodium sps (SFH)	3	0	0	0	9	0	21	0	0
Cyperus sps (SFL)	0	2	0	0	0	0	0	0	0
Dactyloctenium sps (SFL)	0	0	0	0	0	0	0	0	0
Digera sps (SFH)	3	2	0	15	0	0	0	0	0
Digiteria sps (SFH)	3	0	9	0	35	0	0	0	0
Euphorbia sps (SFH)	0	6	0	0	9	0	0	0	0
Mollugo sps (SFH)	25	84	26	0	43	23	21	0	31
Phyllanthus sps (SHH)	0	1	0	0	0	0	0	0	0
Solanum sps (SFH)	0	2	9	0	9	0	10	0	0
Trianthema sps (SFH)	9	7	0	0	9	45	0	0	0
Urochloa sps (SFL)	3	43	0	0	9	0	42	0	0
Total Weeds	52	150	53	15	140	68	167	0	31

SHH = Small Headed Heavy
SFL = Small Free Light
SFH = Small Free Heavy

lower than those of Occupation I. In other words, with the given data, it is suggested that the usage of the crop is higher in Occupation I as compared to Occupation II, even though one stratum of Occupation II has the highest densities of Eleucine sp.. The fill strata, stratum 6 and stratum 4 have relatively lower standardized densities of this crop seed.

This pattern of distribution can be explained when the occupational stratigraphy at the site is examined in more detail. Occupation II (strata 5, 5A and 5B) consists of compacted series of occupation floors which have food preparation features such as hearths, ovens and ash pits (Possehl 1990). Similarly, Occupation I (strata 6A, 6B and 6C) comprises occupation surfaces with high densities of ceramics and other domestic features. Yet Eleucine sp. is absent in strata 5B and 6C (Table 6-3). Strata 6 and 4 are softer fills separating the different occupation events. The high frequencies of Eleucine sp., particularly in Occupation II stratum 5A, can be correlated to the fact that the food preparation features occur in these strata. Similarly the high frequencies in Occupation I in general can be attributed to these levels being occupation surfaces where the crop was used (processed or consumed). It is important to note, however, that Eleucine sp. does not exhibit differential correlation to context. The crop seeds are equally distributed between samples from feature contexts and non-features context (Table 6-4). The presence of the crop seeds in fill deposit strata such as 6 and 4, can be explained through infiltration of these seeds into these deposits. Of importance is the fact that they are present in very low frequencies and densities. Therefore the significantly lower frequencies in these strata contrasts markedly from the patterns in other occupational deposits. Movement of a few small sized seeds is quite likely through the looser sediments of the strata 6 and 4. Thus the low frequencies of the crop in these strata make the above supposition (that they are infiltered from above layers) more plausible.

Table 6-4. Oriyo Timbo: Archaeobotanical Standardized Densities by Context

	Absolute Data			Standardized Data	
DATA	Non-Feas	Features		Non-Feas	Features
Volumn Floated	1042	620		1000	1000
Carbonized Seeds	270	130		259	210
Eleucine sps	50	24		48	39
Panicum miliare	27	8		26	13
Setaria sps (Total)	66	8		64	13
S.italica	38	4		37	6
S.glauca	2	1		2	2
S. tomentosa	26	3		25	5
Unidentifiable millets	2	4		2	6
Total Carb millets	143	44		140	71
Phaseolus mungo	18	4		17	6
Brassica sps	0	1		0	2
Unidentifiable legumes	4	1		4	2
Total Legumes	22	6		21	10
Amaranthus sps (SFH)	3	0		3	5
Carex sps (SFH)	8	4		8	6
Chenopodium sps (SFH)	1	2		1	3
Cyperus sps (SFL)	0	2		0	3
Dactyloctenium sps (SFL)	0	0		0	0
Digera sps (SFH)	3	1		3	2
Digiteria sps (SFH)	6	0		6	0
Euphorbia sps (SFH)	6	0		6	0
Mollugo sps (SFH)	64	27		61	44
Phyllanthus sps (SHH)	1	1		1	2
Solanum sps (SFH)	4	1		4	2
Trianthema sps (SFH)	6	6		6	10
Urochloa sps (SFL)	3	36		3	58
Total Weeds	105	80		102	135

SHH = Small Headed Heavy
SFH = Small Free Heavy
SFL = Small Free Light

Panicum sp.: A total of 35 carbonized grains of Panicum sp. were recovered, comprising 8% of the total carbonized seed assemblage at the site (Table 6-1). All these seeds were identified as being those of Panicum miliare. The average measurements of these grains were 1.4mm for length, 1mm for width and .9mm for thickness.

Panicum miliare seeds are used as human food ethnographically. The seeds are consumed both cooked as rice or ground into flour to make bread and porridge. The vegetative parts of the plant are equally valuable as green fodder and in a dry state. Panicum miliare straw is also used as packing material due to its softness. The crop grains store well for long periods of time, both in a husked and dehusked state, and ethnographically it was noted that the storage period is relatively long for Panicum miliare (often upto a couple of years).

The Panicum miliare seeds were recovered from all the five trenches albeit in varying frequencies (Table 6-2). Panicum miliare occurs in the highest standardized densities in Occupation II of trench S2. In particular within Occupation II, stratum 5A has the highest standardized density, while they are absent in stratum 5B and occur in low frequencies in stratum 5 (Table 6-3). This distribution within Occupation II is comparable to the Eleucine distribution. The distribution of Panicum miliare seeds in Occupation I strata is distinct from that of Eleucine in that it occurs in significantly lower densities. Specifically within Occupation I, Panicum miliare is absent in strata 6A and 6C, and occurs in low frequencies in stratum 6B (Table 6-3). Additionally, Panicum miliare seeds occur in higher standardized densities in contexts not related to features (Table 6-4). In other words, they do not occur predominantly in samples of features and such specific contexts, rather they occur in the general deposits.

The distribution of Panicum miliare can be explained to an extent through stratigraphic associations. The seeds of this plant occur in significantly higher densities in Occupation II and in lower frequencies in Occupation I. As noted in the discussion

for Eleucine distributions, Occupation II is associated with food preparation features, and Occupation I has occupations surfaces. Since Panicum miliare occurs in the strata associated with food preparation more significantly than those associated with occupation surface, this suggests the status and role of the crop plant is related primarily to human consumption.

Setaria spp.: A total of 74 carbonized seeds identified as Setaria spp. were recovered from 4 of the 5 trenches (Table 6-1). Three species are represented by this assemblage: Setaria italica, Setaria glauca and Setaria tomentosa. The measurements of carbonized Setaria italica averaged 2.4mm for length and 1.2mm for width; Setaria tomentosa averaged 1.9mm for length and 1.1mm for width; and Setaria glauca averaged 3mm for length and 1.6mm for width.

Trench S5 has no Setaria spp. or Eleucine sp. seeds, and as expected from the distribution patterns of the other millets, Trench S2 has the highest standardized densities of Setaria spp. seeds (Table 6-2). Trench S5 has a very low frequency of millet grains, and carbonized seeds in general. Stratigraphically, Setaria spp. occurs in the highest frequency in Occupation II (Table 6-3). Within this occupation, stratum 5A has the highest standardized density, with strata 5 and 5B showing lower frequencies. Occupation I has relatively lower densities for Setaria spp. This pattern of distribution is similar to that of Panicum miliare in that the usage of these two millet crop seeds is higher in Occupation II as compared to Occupation I, and this is in contrast to the usage of Eleucine sp. crop seeds. Setaria spp. occur in strata which have features and contexts related to food preparation and disposal. Even though the seeds do not show higher densities or specific association with samples from features (Table 6-4), it is argued here that they occur in significantly higher densities in the strata associated with food

preparation because their primary role was as food for the inhabitants.

Of the different species represented by the assemblage of Setaria spp., Setaria italica occurs in the highest frequencies, followed by Setaria tomentosa and Setaria glauca occurs in lower frequencies. Based on this pattern and ethnographic information on the use of Setaria spp. as food, it is asserted that Setaria italica is being used as food most prominently among all the Setaria spp. represented at the site.

Note: 8 carbonized seeds were tentatively identified to be those of Pennisetum sp. in the preliminary report (Reddy 1991b). This identification is now retracted after further detailed study of these seeds has confirmed that they are not those of Pennisetum sp.

Additionally, in the preliminary report (Reddy 1991b) three unidentified seeds were reported as Seed A. They have been identified subsequently as Digera sp. weed seeds. They are well carbonized, and show no distortion. Their average measurements are 2.3mm for diameter, 2mm for width and 1.3mm for thickness. They are round with very tiny and not very prominent surface spikes. The seeds taper sharply to an apex, and maintain the round shape.

Legumes: A variety of legumes have been recovered from all 5 trenches, comprising 29 carbonized seeds (Table 6-1). Standardized data shows that S2, and Occupation II has the highest densities for legumes (Tables 6-2, 6-3). The presence of legumes, or any other seeds, in the archaeologically sterile stratum 7, is probably due to infiltration of seeds through the sediment and other pedological activities. The legumes include two identified crops, those of Phaseolus mungo and Brassica sp.. Six seeds were identified as being those most closely related to legumes, but further identification was not possible due to the fragmentary nature of the seeds. The diagnostic parts of these seeds which would facilitate identification were missing.

Phaseolus mungo is also known as Vigna angularis or black gram. This legume is used as human food and the vegetative parts of the plant are popular as fodder. The legume seeds are rectangular, smooth and do not always have a clearly distinct hilum scar. This legume is an important dry land crop in India, and is usually cultivated in low rainfall conditions (Aiyer 1982). It grows best in clayey and black cotton soils, and its presence indicates summer cultivation. The 22 seeds fragments of Phaseolus mungo, were recovered from 4 trenches, and they occur in higher frequencies in Trench S2 and S5 (Table 6-1, 6-2). Stratigraphically Phaseolus mungo occurs in significantly higher densities in Occupation II, specially stratum 5A (Table 6-3). Occupation I has lower frequencies of the legume and the fills between the occupations, strata 6 and 4 have significantly lower frequencies of the legume but a considerable number nonetheless. This pattern is similar to the distribution patterns of Panicum miliare and Setaria spp. All the crop plant seeds occur in significantly higher frequencies in stratum 5A of Occupation II. Again, as in the case of the millet crop seeds, the seed fragments of Phaseolus mungo do not occur in higher frequencies in samples from features and related specific contexts, instead they occur in higher frequencies in the general deposits (Table 6-4).

The other legume crop represented is Brassica sp.. Only one seed of this plant was recovered from Trench S6 Occupation I. Brassica sp. is a crop plant in India, and is often grown in widely different conditions of climate. Since there is only one seed of this crop, further discussion on its presence and implications is not warranted.

Non-Crop Plants: A total of 190 seeds were recovered which have been grouped as 'weeds' (Table 6-1). They are grouped together because they do not represent any major crops (as crops are defined today), although it is quite likely that some of them

might have been specifically collected for food, for example Amaranthus sp., Chenopodium sp., Dactyloctenium sp., and Solanum sp.. The weeds at Oriyo Timbo includes 13 different genera of plants and represents a variant group which could later be used for further interpretation of the archaeobotanical assemblage of Oriyo Timbo. Following are the weeds and their frequencies: Amaranthus sp. (3), Carex sp. (12), Chenopodium sp. (4), Cyperus sp. (2), Dactyloctenium sp. (1), Digera sp. (4), Digitaria sp. (6), Euphorbia sp. (6), Mollugo sp. (92), Phyllanthus sp. (1), Solanum sp. (5), Trianthema sp. (11) and Urochloa sp. (43) (Table 6-1).

These 13 different genera can be classified into the different weed categories developed in chapter 5. The resulting categorization reveals the presence of three weed categories, and the weed assemblage is dominated by small free headed weeds (SFH) with about 69% of the weeds. The small free light (SFL) weed category constitutes 23%, while the small headed heavy category (SHH) has a lower frequency of 8%. It is important to note that no big sized seeds are present, nor are any small headed light (SHL) category of weed seeds present. The ethnographic modeling presented in chapter 5 has demonstrated that specific categories of weeds can be used as indicators of different stages of crop processing, and the categories present in the Oriyo Timbo weed assemblage (SFH, SFL and SHH) will be used in chapter 7 to shed light on what the archaeobotanical assemblage at the site is most indicative of: earlier processing stages or later processing stages. This information can be used to determine whether the crops were cultivated at the site or brought in through exchange from elsewhere.

Mollugo sp. weed seeds occur in the highest frequencies, and they constitute the majority of the weed assemblage (Table 6-1). The seeds on average measure 1.1mm in length, 1.0mm in width and .8mm in thickness. The seeds have a distinctive marked surface of regulose lines in curved rows, the curves following the coil of the seed embryo. They are present in significantly higher frequencies in Trench S8 Occupation

II. They occur in lower frequencies in Occupation I and the fills between the occupations (Table 6-3). It is interesting to note that Occupation II stratum 5A, which had highest frequencies for millet seeds and legume seed fragments, has relatively low frequencies of Mollugo sp. seeds. The implications of this distribution to the interpretation of the site's subsistence economy and also the role of Mollugo sp. will be addressed in the next chapter along with other related issues.

As an assemblage, weeds occur in the highest densities in Occupation I, followed by Occupation II (Table 6-3). Additionally the weeds at Oriyo Timbo occur in somewhat higher frequencies in the occupation surfaces associated with food preparation features (Table 6-4). This significant pattern will be subsequently used in chapter 7 to interpret the role of millets, legumes and weeds at Oriyo Timbo.

Spatial Trends

The absolute counts of the carbonized seeds were converted into standardized densities (number of seeds per 1000 liters of sediment), so that the data from different trenches could be easily compared (Table 6-2). This reveals variation in the distribution of carbonized seeds among the trenches. Trench S8 has the highest standardized density with 457 seeds per 1000 liters, S6 and S2 follow with 344 and 331 seeds per 1000 liters. S9 and S5 have lower frequencies with 127 and 75 seeds per 1000 liters (Figure 6-2). Although trench S8 has the maximum number of features and ash pits, it appears that there is a direct association between the context of the sample and the density of seeds recovered and this will be discussed in the subsequent sections.

Millets (summer crops) occur in highest frequencies in Trench S2 and S6, with S8 falling in the middle and, S5 and S9 have the lower frequencies (Figure 6-2). The genera distribution is quite consistent in that the various millets occur in similar

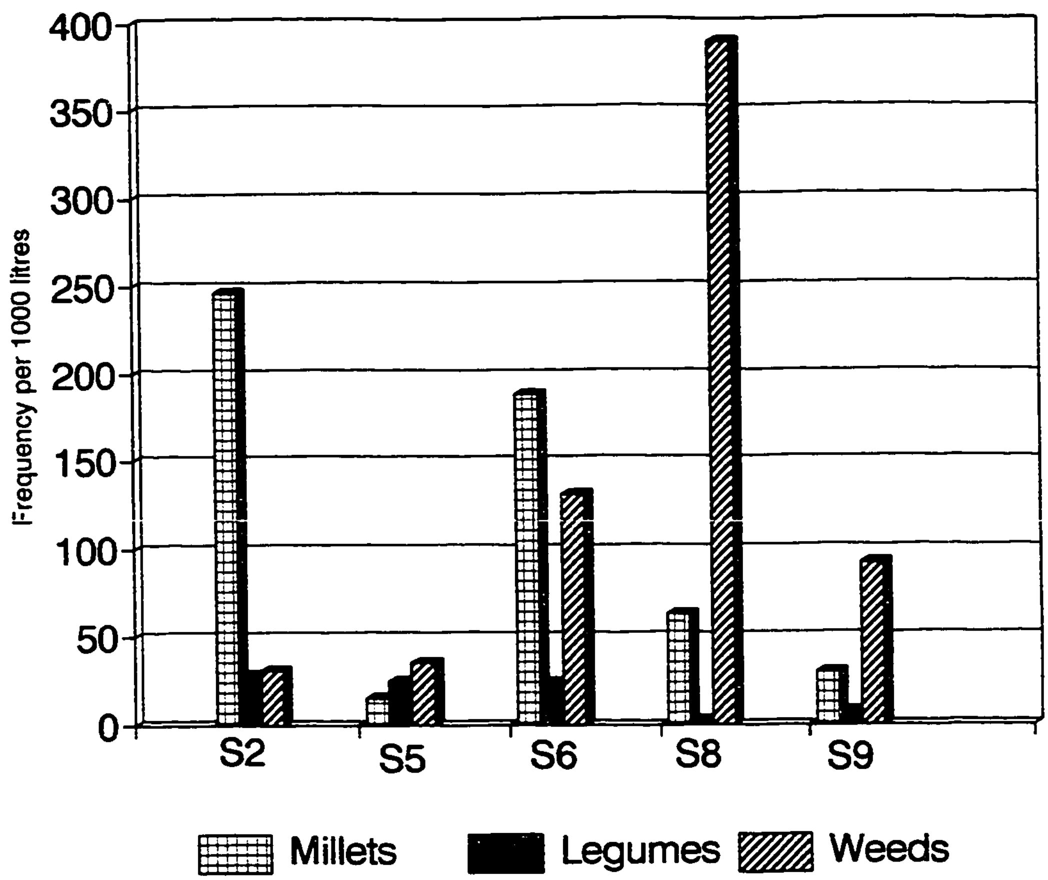


Figure 6-2. Oriyo Timbo: Spatial Distribution of Millets, Legumes and Weeds

frequencies in all the trenches (i.e., highest frequency in trench S2, and lowest in S9). It is interesting to note that Trench S5 does not have any Eleucine sp. and Setaria spp. Weeds dominate the archaeobotanical assemblage of trench S8, specifically the weed seeds of Mollugo sp. (Figure 6-2). They also occur in higher frequencies in comparison to crop plants particularly in trench S9. The implication and association of this weed is discussed in the section on contextual patterns.

Stratigraphic Patterns

Stratigraphically, the relative density distribution reveals that Occupation II has the highest frequency of carbonized seeds (Table 6-3). Within Occupation II, stratum 5A has the highest frequency. Occupation I has lower densities of carbonized seeds but they are significantly higher than the densities of carbonized seeds in the fills between occupations. These results correlate well with the archaeological stratigraphy related to food preparation features.

The distribution of millets and legumes reveal that Occupation II, specifically stratum 5A, has the highest frequency of these crop seeds while weeds occur in particularly low frequency (Figure 6-3). The implications of this variation are significant and will be explored in chapter 7. Eleucine sp., Panicum miliare and Setaria spp. occur in the highest frequency in stratum 5A of Occupation II. Additionally, legumes, specifically Phaseolus mungo also occur in the highest frequencies in stratum 5A of Occupation II (Figure 6-3). Among the weed species the most dominant Mollugo sp. weed occurs in the highest frequency in Occupation II. Thus, Occupation II, and within it specifically stratum 5A has the highest density of carbonized seeds (Figure 6-3). Because of the disturbed nature of the site further stratigraphic interpretations are not made, and emphasis is primarily placed on the contextual relationships discerned from the Oriyo Timbo data.

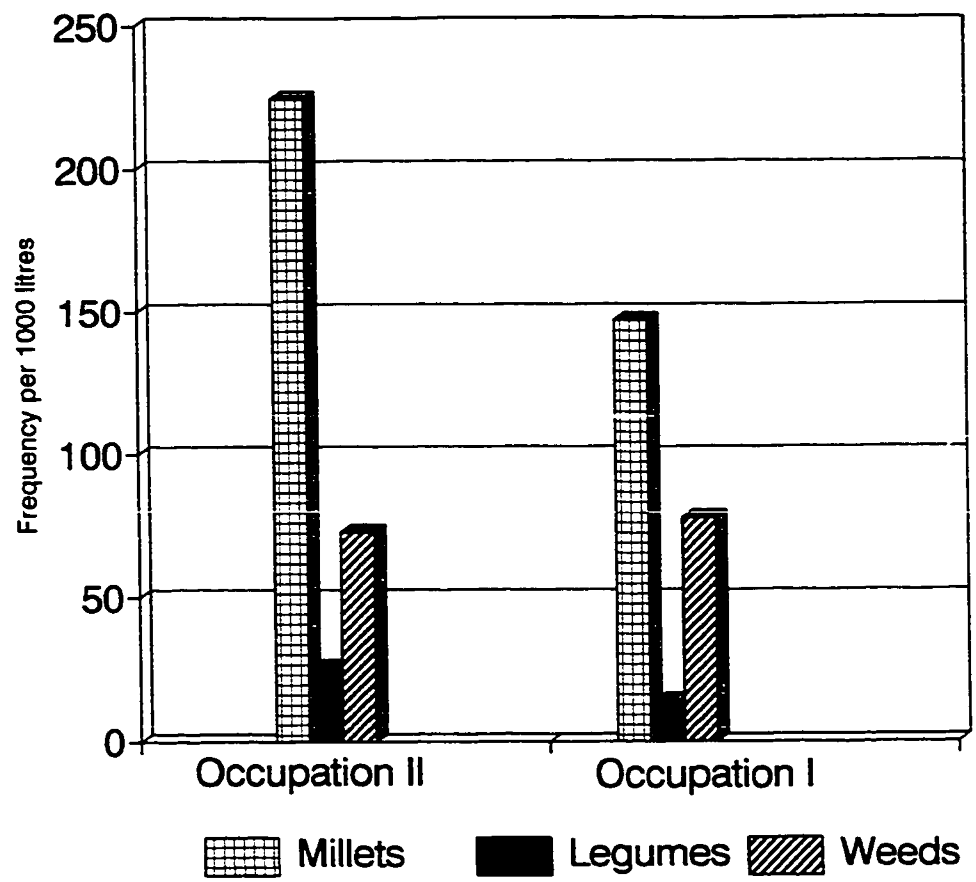


Figure 6-3. Oriyo Timbo: Occupational Distribution of Millets, Legumes and Weeds

Contextual Relationships

The context of the samples is critical to their ultimate interpretation, and also to the interpretation of the archaeobotanical assemblage at the site. The context of the samples can be indicative of the motive for their intensive use, initial discard and their status in the archaeobotanical assemblage. At Oriyo Timbo, the samples are mostly from general sediment deposits within the occupation surfaces and fills not associated with specific contexts. However, there are some samples which come from definite contexts and features related to food preparation and dumping/discard. These contexts are positive indicators of human behavior specifically in relationship to the plant materials, and the following discussion on the contextual patterning of the archaeobotanical materials will stress these implications.

Trench S2 has no samples from features or related contexts, thus all the samples studied from this trench are those from the general sediment deposits associated with the different occupations and fills. It is however interesting to note that trench S2 has the highest frequency of carbonized millets and legumes seeds and lower frequencies for weeds (Table 6-2, Figure 6-2). Among the millets recovered in Trench S2, Setaria spp. dominates the millet assemblage, with Eleucine sp. and Panicum miliare occurring in moderate amounts. The legume category in the trench primarily includes Phaseolus mungo. The archaeobotanical assemblage from this trench is thus dominated by seeds of crop plants.

The contexts of these seeds from Trench S2 (of general deposits/fills) are more indicative of an amalgam of different activities resulting from various events which lack resolution due to several factors. Included among these factors are the nature of the site, locations in which specified activities do occur, post depositional events which might have obscured these activities, and lastly repetition of activities within spatially confined areas (or the lack of such repetition in Trench S2).

The majority of samples from Trench S5 (80%) are from general deposits related to occupation surfaces and fills, although 20% are from specific features contexts related to food preparation and dumping/discard. In general there is a low frequency of carbonized seeds recovered in this trench (Figure 6-2). Millet seeds, represented only by Panicum miliare occur in lower relative frequencies, legumes (represented only by Phaseolus mungo) occur in moderate amounts while the weed seeds dominate the archaeobotanical assemblage of this trench.

In trench S6 10% of the samples are from features, feature fills, and fills outside of features. Recovery of carbonized materials from this trench was moderate to high and it has the second highest densities at the site. Millets dominate the archaeobotanical assemblage from S6, weeds constituting a strong percentage, and legumes occur in low frequencies (Figure 6-2). Among the millets, Eleucine sp. and Setaria spp. seeds dominate, while Phaseolus mungo and Brassica sp. constitute the legume category. Trench S6 has the widest range of weed species, with different species in widely varying frequencies.

Stratigraphically all the features in trench S6 are in occupations II and I. The samples from ash pits and food preparation features contain carbonized seeds of Eleucine sp., Panicum miliare, Setaria spp., Carex sp., Mollugo sp. and Trianthema sp.. A clay lined feature, however, had no carbonized seeds. The ashy pit contents were most probably cleanings and dumpings from living floors, including food preparation areas.

In trench S8, 40% of the samples are from contexts related to food preparation and dumping/discard. The recovery of carbonized seeds is high regardless of contexts, and it has the highest densities of carbonized seeds at the site. However, the frequencies of millet seeds and legumes is relatively low (Figure 6-2).

The archaeobotanical assemblage of the trench is dominated by weed species seeds (85%). Mollugo sp. is most dominant, constituting over 90% of the weed species. Mollugo sp. most often grows as a weed in crop fields. The seeds are inedible, though the leaves could have been consumed. In trench S8, samples from contexts of ashy pit features (which are most probably cleanings from the food preparation areas and living floors) and scrapings above burnt hearth surfaces contain a high percentage of Mollugo sp. seeds. It is very likely that the Mollugo sp. seeds were contaminants in the food grains and were selected out and ultimately found their way into the discard/dumping contexts that are found archaeologically. It is also likely that they were a part of the fuel used in the specific area (intentional or unintentional). Further implications of these associations will be addressed in chapter 7 where the ethnographic models developed in chapter 5 will be tested.

Samples from defined contexts in trench S8 vary in distributions of plants. A feature shaped like a keyhole (most likely a hearth) in Occupation II is sterile for carbonized seeds. Samples from features, ashpits and fills above hearth/burnt surfaces are dominated by weeds while millets seeds show relatively lower densities in these contexts. The seeds include Eleucine sp., Setaria tomentosa, Setaria italica, legumes, Digera sp., Cyperus sp., Solanum sp. and Urochloa sp..

Trench S9 has the highest number of samples (81%) from defined features related to food processing and discard/dumping. In this trench, the samples in the fill separating Occupation II and III (stratum 4) are sterile for carbonized plant remains, while, the samples from Occupation II have preserved carbonized seeds. The contexts of these samples are feature fills, fills around, above and below features. This includes a tandoor/oven wall with one carbonized seed of Mollugo sp., while the fill of the tandoor/oven has 3 carbonized seeds of Mollugo sp. seed and considerable charcoal. Sediments from three hearths in Trench S9 were also processed for plant remains. Of

these, only one hearth has scanty plant materials preserved, comprising of one Eleucine sp. carbonized seed.

Contextual patterns in Oriyo Timbo archaeobotanical data indicate that features not directly related to food preparation, such as hearth and oven contents, have a better recovery of carbonized crop seeds such as those of Eleucine sp., Setaria italica, Setaria tomentosa, Panicum miliare and Phaseolus mungo (Figure 6-4). These contexts include fills around, above and below the hearths and a range of ashy features. The implications of this patterning is significant. Thus, it is argued that Oriyo Timbo carbonized plant remains appear to be differentially preserved based on context (Reddy 1991b). Contexts with the highest probability of fire and high temperatures, such as hearth contents, tandoor/oven fills and walls, all appear to have very low frequency of carbonized seeds. Whether this correlation is a result of a lack of preservation due to the high temperatures in these contexts, or a result of no seeds being associated or incorporation into these contexts is a challenging question. It is asserted here that there is a very high probability of seeds accidentally getting incorporated into hearths during food preparation, but the high temperatures of the hearths would have reduced them to ash very soon after, therefore their survival would be minimal. Ethnographic observations revealed that accidental spillage of seeds during food preparation and also during the cleaning process before food preparation is very likely and occurs in a significant number of incidents. Thus for Oriyo Timbo, it is argued that the significantly low densities of carbonized seeds from hearths is due to their being destroyed as a result of the high temperatures rather than not being initially incorporated into this context.

It has also been noted at Oriyo Timbo that the highest frequency of seeds occurs in samples from deposits around, above and below features (Figure 6-4). This is due to

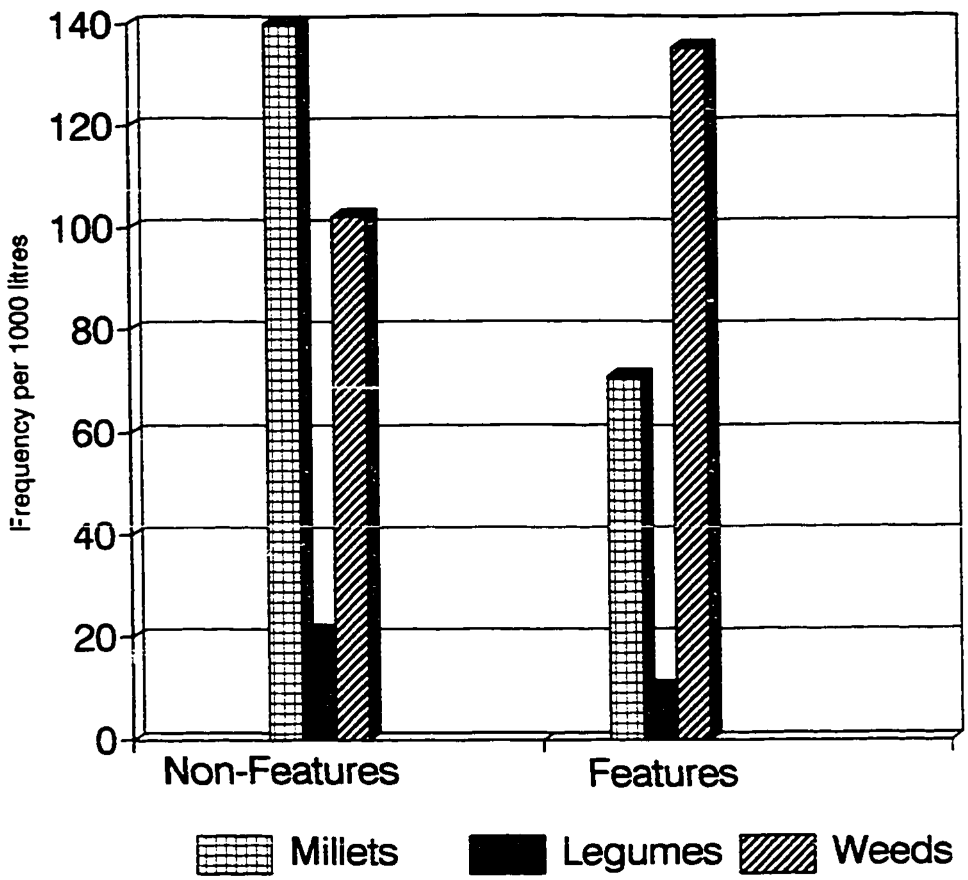


Figure 6-4. Oriyo Timbo: Contextual patterns of Millets, Legumes and Weeds

depositional processes during and after these activities. For example, in India, most final cleaning of food grains is done nearby or around the hearth (almost as an after thought) most often directly before the food preparation. Sometimes the cleaning occurs in the front porches/yards. In either case, the cleanings are most often swept into the hearth after the cooking is done, that is while the fire is dying or after the fire is put out. This provides the ideal temperature for the seeds to be carbonized but not destroyed into ash. Subsequent cooking, however, might destroy these seeds unless the hearth was abandoned soon after such an event (which is what we would then discover archaeologically), or that the hearth was cleaned out and the contents disposed into a trash/dump area. In either case, it is important to note that intentional and unintentional discard of crop grains occurs in these contexts due either to their immaturity, other undesirable quality, or accidental disposal.

Miller and Smart (1984) have suggested that a significantly high percentage of archaeobotanical materials retrieved from living floors, hearths and ovens are preserved as a result of dung being intentionally burnt as fuel, and also due to dung plastering of floors. However, it is important not to subsequently assume that the archaeobotanical materials from these contexts specified by Miller and Smart (1984) are related to animal fodder. It is equally probable that the grains included in dung could come from elsewhere (i.e., inclusions when the dung was dropped, dried, packed, etc.), rather than just from the animals digestive system. These variables can only be controlled and explained upon thorough understanding of the context of the archaeological sediment. Alternatively, dung need not be the primary source of seeds in archaeological sediments. Crop byproducts are also often used as fuel in the Third World, although millet byproducts rank quite low as attractive domestic fuels when compared to wheat, barley and sugarcane crop byproducts (Barnard and Kristoferson 1989:79). So how can one understand the contextual distribution of the carbonized seeds recovered at Oriyo

Timbo ? I propose that most of the crop seeds recovered at Oriyo Timbo are not from dung being used as fuel, but rather their inclusion in the archaeological record is evidence of their use as food. This hypothesis will be tested in chapter 7 through the application of ethnographic models.

Summary of Oriyo Timbo

To summarize the Oriyo Timbo 1989-90 archaeobotanical results, there is strong evidence for the use of summer crops. There is patterned variation in the frequencies of carbonized seeds recovered between trenches. Square S8 has the highest frequency of weed seeds, which accounts for it having the highest frequency of total carbonized seeds, while S2 has the highest frequency of millets (Figure 6-2). Stratigraphically Occupation II and I have higher frequencies of seeds as compared to the fills between the occupations (Figure 6-3). There is a significant difference between the densities of carbonized seeds recovered from Occupation II and I, with Occupation II having significantly higher densities of carbonized seeds. Given this pattern coupled with the higher number of food preparation features in Occupation II, it is argued that at Oriyo Timbo there is an increase in crop plant seed usage over time, that is from Occupation I to Occupation II.

It is also clear that the distribution of carbonized seeds at the site is not concentrated in any functional locus, such as a hearth or oven. In fact, the samples from these contexts, show a relatively low density of seeds compared to the general sediments from the different trenches (Figure 6-4). This may be due to several reasons, the most probable being that the preservation of seeds in these contexts is lower due to the high temperatures of cooking and burning which would totally destroy the archaeobotanical materials.

There are several important questions that need to be answered to fully understand the Oriyo Timbo archaeobotanical assemblage and subsequently interpret the subsistence economy at the site. These questions, as already discussed, include whether the summer crops such as Eleucine sp., Setaria spp. Panicum miliare and Phaseolus mungo were cultivated at the site or nearby, or were brought as grain from other locals? Equally important is the need to elucidate the economic importance of these crops to the Oriyo Timbo inhabitants. If the crops were being cultivated, was this cultivation the primary subsistence activity, or were there other supplementary activities including herding of cattle, seasonal migrations, and pastoralism complementary subsistence activities, as suggested by the first season of excavations in 1982 (Rissman 1985; Rissman and Chitalwala 1990)? Also what were the millets used for primarily, food for humans and fodder for animals?

The archaeobotanical assemblage at Oriyo Timbo is dominated by weeds, although the millet seeds also occur in strong densities. These weeds are critical in defining the nature of the assemblage with respect to local or non-local cultivation. The characteristics of the weeds (as defined by the different weed categories presented earlier in the chapter) will be used to infer the different processing stages as addressed in chapter 5.

Additionally the Oriyo Timbo archaeobotanical assemblage consists primarily of plant seeds, and has no rachii or any other plant parts. Their presence would have been an indicator of lower levels of crop processing, and of cultivation at the site (see chapters 5 for full discussion of this issue). Thus given the nature of the assemblage and the lack of storage heaps or facilities, and the high proportions of weeds to summer crops, it is hypothesized that the summer crops were not cultivated by the site occupants. However, this assertion will be tested in chapter 7 when ethnographic modeling is applied to the archaeobotanical data to further evaluate whether the

archaeobotanical assemblage at Oriyo Timbo is most comparable to a situation when crops are brought in from elsewhere or cultivated by the inhabitants. Once this is established, the status of the millet crops (whether they were used primarily as human food or animal fodder) and the economic importance of millets for the Oriyo Timbo inhabitants can be addressed.

BABAR KOT ARCHAEOBOTANICAL RESULTS AND DISCUSSION

The adoption of millets into the South Asian subsistence system has been an issue of considerable debate among archaeologists. In addressing the role and importance of millets during the Late Harappan, the site of Babar Kot in Gujarat provides a very rich archaeobotanical assemblage. The archaeobotanical research at Babar Kot strongly indicates that millet and summer cultivation was an established economic activity at this Late Harappan site in Saurashtra. The main crops utilized at the site are 'millet' crops (such as Setaria spp., Panicum sp. and Eleucine sp.), Linum sp. and several legumes. It is hypothesized that these crops were cultivated at the site, however, the degree of importance of each varies considerably. The final objective of this archaeobotanical study is to present a working model for the economic importance of the millet crops (such as Setaria spp., Panicum sp. and Eleucine sp.) in the subsistence system at Babar Kot.

During the first season of research at Babar Kot (1990-91), both carbonized and uncarbonized seeds were recovered from the excavation trenches. The sediment samples from Babar Kot averaged 7.8 liters in volume, and the archaeobotanical recovery averaged 18.25 carbonized seeds per liter of soil sediment. The high density of seeds at the site is primarily associated with burnt soil rather than with high quantities of charcoal. This association is similar to the pattern of archaeobotanical

recovery at the site of Oriyo Timbo where the contexts with high quantities of charcoal appeared to have the lowest frequency of carbonized seeds (Reddy 1991b: 81).

The plant remains occur in varying frequencies across the excavated trenches. For the purpose of the archaeobotanical discussion, the excavation areas will be referred to as mound units and slope units. The recovery of carbonized archaeobotanical materials is higher in the slope units, as compared to the mound units (Table 6-5). However the proportions of millets to legumes to weeds is similar in both the slope and the mound units. There is patterned variation in the stratigraphic distribution of the carbonized seeds in general and also the groups of plants (i.e. millets, legumes and weeds). Occupation III shows the highest density of carbonized seeds recovered, while occupations II and I show a lower but similar recovery (Table 6-7).

Seeds of crop plants such as Setaria spp. and Panicum spp. occur in significant amounts at the site, while those of Linum sp., Eleucine sp., Lathyrus sp., Lens sp. and Vicia sp. occur in lesser amounts. Most of these crops are summer cultivated plants. A variety of non-crop seeds were also recovered including those of Aizoon sp., Carex sp., Chenopodium/Amranthus sp., Cyperus sp., Digitaria sp., Echinochloa sp., Eragastis sp., Ficus sp., Lotus sp., Medicago sp., Phyllanthus sp., Polygonum sp., Solanum sp., Trianthema sp., Urochloa sp. and Zizyphus sp. Of the total assemblage at Babar Kot, summer cultivar seeds comprise 86%, legume crop/winter cultivar seeds comprise 0.4% and non-crop seeds comprise 6%. Among the crop plants, Setaria spp. are by far the most prevalent (92%), while Lens sp. is the most frequent among the legumes (67%). Urochloa seeds account for the most ubiquitous non-crop plant (48.6%) (Tables 6-5 and 6-6).

Table 6-5. Babar Kot: Archaeobotanical Absolute Counts in the Mound and the Slope

DATA	26L	26M	Mound Total		36M	38P	40M	40N	Slope Total
Flot vol (litres)	285	52	337		6	129	62	29	226
Total Seeds	1445	250	1694		11	15552	168	1094	16825
Total Unid Seeds	326	0	326		0	629	20	111	760
Big seed frags	2	0	2		0	8	0	0	8
Nut shells	0	0	0		0	2	0	0	2
Eleucine coracana	6	2	8		0	0	0	0	0
Panicum sps (Total)	432	2	434		0	721	15	55	791
P.miliaceum	0	0	0		0	0	0	4	4
P.miliare	432	2	434		0	721	15	51	787
Pennisetum sps	0	0	0		0	1	0	0	1
Setaria sps (Total)	455	238	693		11	13670	37	553	14271
S.glauca	6	5	11		0	0	0	0	0
S.italica	447	233	680		11	13348	36	553	13948
S.viridis	2	0	2		0	0	1	0	1
S.spks w/rachillae	0	0	0		0	322	0	0	322
Cereal Rachii	8	2	10		0	28	0	3	31
Total Millets	901	244	1145		11	14420	52	611	15094
Linum sps	0	0	0		0	7	1	25	33
Brassica sps	0	0	0		0	0	0	1	1
Lathyrus sps	1	0	1		0	0	0	6	0
Lens sps	12	0	12		0	1	2	3	6
Vicia sps	0	0	0		0	0	6	1	7
Total Legumes	13	0	13		0	1	8	5	14
Aizoon sps (SFH)	3	0	3		0	1	0	0	1
Carex sps (SFH)	6	0	6		0	1	1	0	2
Chenopodium sps (SFH)	1	0	1		0	1	0	1	2
Cyperus sps (SFL)	117	0	117		0	55	0	18	73
Digiteria sps (SFH)	0	5	5		0	78	26	101	205
Echinochloa sps (SFH)	1	0	1		0	1	0	12	13
Eragastis sps (SFL)	0	0	0		0	171	0	0	171
Ficus sps (SFH)	0	0	0		0	0	1	0	1
Lotus sps (SFH)	0	0	0		0	2	1	0	3
Medicago sps (SFH)	0	0	0		0	0	1	1	2
Phalaris sps (SFL)	2	0	2		0	0	0	0	0
Phyllanthus sps (SHH)	1	0	1		0	0	0	6	6
Polygonum sps (SFL)	11	0	11		0	0	0	0	0
Solanum sps (SFH)	2	1	3		0	0	0	0	0
Trianthema sps (SFH)	53	5	58		0	11	21	0	33
Urochloa sps (SFL)	0	0	0		0	158	36	202	396
Zizyphus sps (BFH)	0	0	0		0	6	0	1	7
Total Weeds	197	11	208		0	485	87	342	915

SFH = Small Free Heavy SFL = Small Free Light
SHH = Small Headed Heavy BFH = Big Free Heavy

Detailed Species Discussion

Eleucine sp.: A total of eight caryopsis of Eleucine coracana were recovered, exclusively from the mound units (Table 6-5). All these seeds were measurable, and the measurements averaged 1.47mm in length and 1.01mm in width. The seeds are small and have a globose shape with a prominently depressed hilum. Carbonization seems to effect the extent of hilum depression, but not the globose shape of the seeds.

Pattern searching in the standardized data shows that stratigraphically, Eleucine coracana occurs only in stratum 4 of Occupation III and stratum 8 of Occupation II (Table 6-7). This millet crop seeds were recovered only from the mound unit, and specifically in non-feature contexts (Table 6-6). Thus, Eleucine coracana is differentially correlated to context, occurring specifically in the non-feature contexts that relate to occupation deposits not associated with any particular activity such as food preparation (Table 6-8). Instead these occupation deposits relate to an amalgam of activities associated with human occupation and subsistence, and not to a specific activity.

Recovery of Eleucine coracana seeds/caryopsis was very low from Babar Kot (as compared to Oriyo Timbo), constituting less than 0.5% of the millet assemblage (while the Oriyo Timbo Eleucine sp. constituted 15% of the millet assemblage). Two issues must be addressed to formalize this observation. First, can the low densities of Eleucine coracana be used to infer lower significance of this crop at this site? In other words is there any particular processing activity specific to Eleucine coracana that would explain these low densities and their inclusion into the archaeological record? Eleucine coracana can be regarded as a Type A or a Type B crop depending on whether it is irrigated or not. When it is well irrigated, the inflorescence heads are distinctly larger and can be selectively harvested as with Type A crops, however when the crop is not irrigated well the heads are smaller and the stalks are thinner and the most effective

Table 6-6. Babar Kot: Archaeobotanical Standardized Densities in the Mound and the Slope

Standardized Densities

TRENCH	26L	26M	MND AVE		36M	38P	40M	40N	SLP AVE
Sediment Vol.	100	100	100		100	100	100	100	100
Total seeds	507	481	494		183	12053	271	3772	4143
Total Unid Seeds	114	0	57		0	488	32	383	226
Big seed frags	1	0	0.5		0	6	0	0	2
Nut shells	0	0	0		0	1	0	0	0.2
Eleucine coracana	2	4	3		0	0	0	0	0
Panicum sps (Total)	152	4	78		0	559	24	190	194
P.miliaceum	0	0	0		0	0	0	14	4
P.miliare	152	4	78		0	559	24	176	190
Pennisetum sps	0	0	0		0	1	0	0	0.2
Setaria sps (Total)	160	458	309		183	10594	60	1907	3187
S.glauca	2	10	6		0	0	0	0	0
S.italica	157	448	303		183	10347	58	1907	3124
S.viridis	1	0	0.5		0	0	2	0	0.5
S.spks w/rachillae	0	0	0		0	247	0	0	62
Cereal Rachii	3	4	4		0	22	0	10	8
Total Millets	317	470	394		183	11176	84	2107	3389
Linum sps	0	0	0		0	5	2	86	23
Brassica sps	0	0	0		0	0	0	3	1
Lathyrus sps	0.35	0	0.2		0	0	0	0	0
Lens sps	4	0	2		0	1	3	10	4
Vicia sps	0	0	0		0	0	10	3	3
Total Legumes	4.35	0	2		0	1	13	16	8
Aizoon sps (SFH)	1	0	0.5		0	1	0	0	0.2
Carex sps (SFH)	2	0	1		0	1	2	0	0.8
Chenopodium sps (SFH)	0.35	0	0.2		0	1	0	3	1
Cyperus sps (SFL)	41	0	21		0	43	0	62	26
Digiteria sps (SFH)	0	10	5		0	60	42	348	113
Echinochloa sps (SFH)	0.35	0	0.2		0	1	0	41	11
Eragastis sps (SFL)	0	0	0		0	134	0	0	34
Ficus sps (SFH)	0	0	0		0	0	2	0	0.5
Lotus sps (SFH)	0	0	0		0	2	2	0	1
Medicago sps (SFH)	0	0	0		0	0	2	3	1.2
Phalaris sps (SFL)	1	0	0.5		0	0	0	0	0
Phyllanthus sps (SHH)	0.35	0	0.2		0	0	0	21	5
Polygonum sps (SFL)	4	0	2		0	0	0	0	0
Solanum sps (SFH)	1	2	2		0	0	0	0	0
Trianthema sps (SFH)	19	10	15		0	9	34	0	11
Urochloa sps (SFL)	0	0	0		0	123	58	697	220
Zizyphus sps (BFH)	0	0	0		0	5	0	3	2
Total Weeds	70.05	22	48		0	376	142	1178	424

SFH = Small Free heavy
SFL = Small Free Light
SHH = Small Headed heavy
BFH = Big Free Heavy

Table 6-7. Babar Kot: Archaeobotanical Standardized Densities by Occupation

Standardized Densities

	Occ III	Occ II	Occ I
Sediment Volumn	100	100	100
Total Seeds	7539	707	715
Total Unid Seeds	(2%) 178	(23%) 164	(15%) 110
Big seed frags	(.02%) 2	(.01%) 1	0
Nut shells	(.01%) 1	0	0
Eleucine coracana	1	1	0
Panicum sps (Total)	357	94	410
P.miliaceum	1	0	0
P.miliare	356	94	410
Pennisetum sps	0.3	0	0
Setaria sps (Total)	6625	393	0
S.glauca	1	3	0
S.italica	6473	329	0
S.viridis	2	0	0
S.spks w/rachillae	150	7	0
Cereal Rachii	14	4	0
Total Millets	(93%) 6998	(70%) 492	(58%) 413
Linum sps	(.1%) 10	(.1%) 1	0
Brassica sps	0.3	0	0
Lathyrus sps	0	0.3	0
Lens sps	2	0.3	25
Vicia sps	2	0	0
Total Legumes	(.05%) 4	(.1%) 1	(4%) 25
Aizoon sps (SFH)	0	0	10
Carex sps (SFH)	1	1	0
Chenopodium sps (SFH)	1	1	0
Cyperus sps (SFL)	31	24	88
Digiteria sps (SFH)	71	0	0
Echinochloa sps (SFH)	3	0.3	0
Eragastis sps (SFL)	81	0	0
Ficus sps (SFH)	0.3	0	0
Lotus sps (SFH)	1	0	0
Medicago sps (SFH)	1	0	0
Phalaris sps (SFL)	0	1	0
Phyllanthus sps (SHH)	2	1	0
Polygonum sps (SFL)	2	4	0
Solanum sps (SFH)	0.3	1	0
Trianthema sps (SFH)	10	10	69
Urochloa sps (SFL)	138	6	0
Zizyphus sps (BFH)	3	0	0
Total Weeds	(5%) 346	(7%) 49	(23%) 167

SFH = Small Free Heavy
SHH = Small Headed Heavy
SFL = Small Free Light
BFH = Big Free Heavy

% = of total seeds

Table 6-8. Babar Kot: Archaeobotanical Standardized Densities by Context

Standardized Densities for Contexts

	MOUND		SLOPE	
	Non-Features	Features	Non-Features	Features
Sediment Volumn	100	100	100	100
Total seeds	350	1251	1625	11718
Total Unid Seeds	79	184	191	436
Big seed frags	1	0	0	6
Nut shells	0	0	0	1
Eleucine coracana	3	0	0	0
Panicum sps (Total)	65	440	92	527
P.miliaceum	0	0	0	3
P.miliare	65	440	92	524
Pennisetum sps	0	0	0	1
Setaria sps (Totals)	156	449	1151	9860
S.glauca	4	0	0	0
S.italica	151	449	1151	9625
S.viridis	1	0	0	1
S.spks w/rachillae	0	0	10	234
Cereal Rachii	3	4	0	23
Total Millets	227	893	1243	10410
Linum sps	0	0	3	22
Brassica sps	0	0	0	1
Lathyrus sps	0	2	0	0
Lens sps	4	4	0	4
Vicia sps	0	0	0	5
Total Legumes	4	6	0	10
Aizoon sps (SFH)	1	2	0	1
Carex sps (SFH)	2	0	0	1
Chenopodium sps (SFH)	0.3	0	0	1
Cyperus sps (SFL)	16	126	0	54
Digiteria sps (SFH)	1	4	22	138
Echinochloa sps (SFH)	0	2	0	10
Eragastis sps (SFL)	0	0	0	128
Ficus sps (SFH)	0	0	0	1
Lotus sps (SFH)	0	0	2	1
Medicago sps (SFH)	0	0	0	1
Phalaris sps (SFL)	1	0	0	0
Phyllanthus sps (SHH)	0.3	0	0	4
Polygonum sps (SFL)	4	0	0	0
Solanum sps (SFH)	1	0	0	0
Trianthema sps (SFH)	14	35	2	23
Urochloa sps (SFL)	0	0	48	263
Zizyphus sps (BFH)	0	0	0	5
Total Weeds	41	169	74	631

SFH = Small Free Heavy
SFL = Small Free Light
SHH = Small Headed Heavy
BFH = Big Free Heavy

harvest is the type B method. For the purpose of prehistoric interpretations, Eleucine coracana is regarded as a Type B crop. Unlike most Type B crops such as Panicum miliare and Setaria italica, Eleucine coracana's caryopsis do not have binding glumes and husk. Instead the caryopsis are more like the naked seeds of Pennisetum typhoides and Sorghum bicolor. Therefore, the processing of Eleucine coracana does not require the roasting stage to help in dehusking. This stage is considered to be very important in the carbonization and inclusion of the seeds into the archaeological context. The implications of its absence in the processing pathway of Eleucine coracana are obvious. This could be one contributing factor to account for the lower densities of Eleucine coracana. However, given the extremely low densities of Eleucine coracana the crop was probably of low importance in the Babar Kot millet assemblage.

The second clarification is related to the use of the plant crop. Would the use of the plant crop effect the recovery of its seeds in archaeological context? For example, if the plant was used only as green fodder (before the seeds were formed), then the importance of the plant to the community cannot be related to low frequencies of the seeds. In the case of the Babar Kot assemblage, the Eleucine coracana seeds do not represent a plant being used solely as fodder. If a plant was cultivated solely for animal fodder, then it is not allowed to mature and seed. Therefore if Eleucine coracana was grown just for fodder, then it is unlikely that even 8 seeds would not have been carbonized nor recovered. Their very presence albeit in significantly low densities is an indication that their use was not limited and restricted to use as fodder. It is quite likely that the plant could have been used as fodder in addition to its use as human food. At this point without other lines of evidence this has to remain a speculation. These issues will be further addressed in chapter 7.

Panicum sp..: A total of 1,225 seeds of Panicum sp. from Babar Kot were

recovered, constituting 7.5% of the millet assemblage (Table 6-5, 6-6). These include 1,221 seeds of Panicum miliare and 4 seeds of Panicum miliaceum. The 1,221 seeds of Panicum miliare include 42 seeds which have been highly distorted but show Panicum miliare characteristics. The average measurements of these carbonized grains were 1mm for length and .55mm for width.

Panicum miliare caryopsis are the second most frequent plant in the crop plant category at Babar Kot. They occur in higher frequencies in the slope units (Table 6-6). Stratigraphically, Panicum sp.. also varied between the two areas excavated (Table 6-7). The lower strata of the mound units have higher densities of Panicum miliare, while the upper strata of the slope units have lower densities.

Panicum miliare shows a differential distribution across the three occupations, with the millet assemblage of Occupation I being comprised only of Panicum miliare seeds. Occupation III has a similar density, but Occupation II has significantly lower densities of Panicum miliare seeds (Table 6-7). The lower densities of Panicum miliare in Occupation II suggests a lower usage of the crop during this Occupation. However, the usage of the crop is primarily as human food since a significant percent of the Panicum miliare in Occupation II come from feature contexts particularly dump pits and a clay feature (related to food preparation) (Table 6-8). In general, the recovery of Panicum miliare seeds (both in the slope and mound units) is significantly higher in feature contexts (as opposed to the recovery of Eleucine coracana which is higher in non-feature contexts). This information indicates that the status and role of Panicum miliare is primarily related to human food. Panicum miliare is considered to be an important crop plant in the Babar Kot assemblage. It is definitely not the dominant millet crop, but it was certainly heavily utilized during occupations III and I (Table 6-7). Its decreased usage during Occupation II can be explained best by correlating it to

the addition of Setaria italica into the millet assemblage during this occupation.

Pennisetum: One seed has been tentatively identified as belonging to the genus Pennisetum (Table 6-5). The seed is partially destroyed and measures 2.11mm in length and 1.9mm in breadth. It was recovered from a slope unit in a feature fill associated with Occupation III. Recovery of the Pennisetum sp. seed is very significant however, considering it singular presence no further discussion is warranted.

Setaria spp.: A total of 14,964 Setaria spp. seeds were recovered from the site (Table 6-5). Of these, 11 seeds are Setaria glauca, 3 seeds are Setaria tomentosa, 14,628 seeds are Setaria italica and 322 are Setaria italica spikelets with rachillas. This genus shows the highest density among the carbonized seeds at the site (Table 6-6). Average measurements of the seeds can be summarized as follows: Setaria italica has an average length of 1.91mm and 1.2mm in breadth, Setaria glauca has an average length of 2.93mm and 1.42mm breadth, Setaria tomentosa has an average length of 2.03mm and 1.01mm breadth. It is proposed that the primary use of Setaria italica at Babar Kot is as human food, though secondary use as fodder, specifically of the crop's byproducts, is quite likely.

Stratigraphically, Setaria spp. occurs consistently in occupations II and III, and overall it appears to be the most intensively used and cultivated crop at the site (Table 6-7). Setaria spp. are however absent in Occupation I, appearing first at the onset of Occupation II, and in very high densities in Occupation III. Setaria spp. spikelets with rachillas are present only in Occupation III. These spikelets with rachillas are key to establishing the status of the crop; in other words the presence of these components (in conjunction with other components such as the different weed categories) are indicators of specific crop processing activities which can shed light on whether the crop was

cultivated by the inhabitants or traded in from elsewhere.

Interestingly, the relative frequency of Setaria spp. varies inversely with the relative frequency of Panicum sp. (Table 6-7). Panicum sp. occur in highest densities in Occupation I and in much lower densities in the later occupations (with the exception of strata 5 and 5a of Occupation III). Setaria spp. are, however, absent in occupation I and increase in frequency in Occupation II to III. This pattern may suggest that Setaria spp. is becoming more important as a food crop at the site at the expense of Panicum sp.. This inference (that changes in the composition of chronologically different assemblages indicate changes in plant resource use) has its limitations since it assumes that the different temporal assemblages were all created by similar processing stages. Unless all the assemblages were recovered from storage facilities, this assumption may not be valid. A much stronger inference regarding changes in plant resource use over time must first examine whether the different assemblages, from various periods, are the result of similar processing stages or not. The ability to correlate particular archaeobotanical assemblages to certain stages in plant processing with some degree of certainly is crucial. Therefore, the nature of the Panicum sp. and Setaria spp. assemblages as they correlate to processing stages in the different occupations has to be addressed, specifically whether different processing stages and activities are responsible for the inversed frequencies of the two crop seeds in the different occupations.

Setaria spp. occurs in significantly higher densities in the slope units as compared to the mound units (Table 6-6). In addition, typically Setaria italica occurs in significantly higher densities in feature contexts rather than general deposits, thus linking these crop seeds unquestionably to specific human activities (Table 6-8). In the slope units, about 90% of the Setaria italica seeds were recovered from feature contexts, while in the mound about 75% of the Setaria italica seeds were recovered

from feature contexts. The Setaria italica spikelets with rachillas also occur overwhelmingly in feature contexts of the slope units (Table 6-8). These spikelets (along with other components) are indicative of specific processing activities, and their occurrence exclusively in the slope units indicate specialized areas of particular food processing activities in these areas. Setaria glauca in contrast occurs only in non-feature contexts and only in the mound units. Setaria viridis does not exhibit any distinctive pattern of distribution. Both of these species, Setaria glauca and Setaria viridis are not considered to have been used as human food, and their presence in the assemblage is attributed to other factors.

Of the 14,628 seeds of Setaria italica, 8,715 seeds were recovered from a seed pocket in Occupation III (stratum 5) of the slope units. It is important to emphasize here that Setaria spp. seeds occur in significantly higher densities in the slope units with or without the inclusion of the seed pocket seeds. The recovery of this seed pocket or lens with carbonized Setaria sp. seeds is of great significance. The seed pocket is predominantly composed of Setaria italica caroypsis (85%), rachii (0.3%) and spikelets with rachillas (3%). An additional 6% of the seeds recovered from this feature are Panicum miliare, and 3% are comprised of Cyperus sp. seeds, Digitaria sp. seeds, Eragastis sp. seeds, Urochloa sp. seeds and Zizyphus seed/nut fragments. Thus, a significant percentage of the seed pocket is of Setaria italica caryopsis.

This archaeobotanical find at Babar Kot is particularly important because to date there have been no similar finds in Gujarat, and the high number of carbonized Setaria spp. seeds which are mostly clumped together in this feature is intriguing. There is no associated disturbance, and there are signs of burnt soil and ash in the vicinity. The seed pocket was found immediately below a distinct feature of loose ashy fine sediment defined as a small pit. Since the trench which contained this feature was excavated by the author, it can be strongly asserted that no insect, rodent or other animal disturbance

were noted. The well-carbonized state of the seeds negates the possibility of insect hole activity, and the clumped nature of the seeds through burning disaffirms the role of disturbance or animal activity. The associated contexts were those of domestic refuge and domestic dumping, with ash pits and domestic discard dominating the unit. Given this situation, it is safe to state that this seed pocket is a direct result of human activity related to food preparation. In this light the burnt and clumped nature of the seeds is very critical to their interpretations. They must have been burnt/charred through intentional or accidental event, and several scenarios can be offered to explain this event.

The first possibility is that the seeds were burnt during one of the crop processing stages, specifically the roasting stage which is done to aid in dehusking. Millets which have tough glumes/husks are very often roasted before the dehulling/dehusking process of pounding. The roasting aids in the efficient and successful removal of the hard clasping husk. It is possible that the Setaria italica seeds were accidentally spilled into the fire during a roasting process. Subsequent cleaning of the hearth and disposal into the domestic dumps resulted in their archaeological inclusion.

Another explanation is that the seed pocket contents are cleanings from last few crop processing stages (for example winnowing III by shaking), which very typically occur in home bases and specifically in the food preparation areas. My ethnographic studies in India have shown that crop products in the last few stages of processing are very often cleaned of unwanted non-crop seeds and tail grains of the desired crop in the homes, often around hearths just before food preparation, or in the yards. The cleanings are then most often swept into trash areas or if the cleaning was indoors then into the hearth. In the case of the Babar Kot seeds pocket, they could have been swept

into a context where they were burnt, and then subsequently disposed into trash dump contexts.

A third possible explanation for the formation of this seed pocket is the inclusion in dung fuel as the results of being used as fodder. The millet grains could have been fed as fodder, and then subsequently the dung (with its undigested fodder seeds) was used as fuel in hearths for cooking. Later the cleanings from the hearths were dumped into the trash contexts.

The last explanation is that they are the crop processing cleaning byproducts that were discarded into domestic areas and then were subsequently accidentally burnt, and entered into the dump context.

I argue that of these explanations the most probable is that the seed pocket represents byproduct cleanings from crop processing activities that were accidentally burnt either by being swept into the hearth or some other means. Subsequently they were deposited into trash contexts. For several reasons, the composition of the seed pocket is most indicative of such a process rather than one related to the roasting of Setaria sp. for dehusking. First, the seed pocket contains two crop seeds, those of Setaria italica and Panicum miliare. If only one crop plant were present, then it can be proposed that these seeds were being roasted for dehusking. However, since two crop seeds are present (albeit in different proportions), it is unlikely that they were both being roasted together for dehusking (i.e. mixed together). The clumped, aggregated and carbonized nature of the seeds negates the possibility that they were burnt separately and then subsequently deposited together. Therefore, the seeds of both crops had to have been carbonized together. The inclusion of two crop seeds into a context that was to be burnt later could have been two separate events, but they were burnt together. This therefore negates the possibility of the millets used as fodder and later the dung used as fuel, because if this scenario was correct then the millet seeds would

not be clumped together.

The Setaria italica crop product cleaning was a deliberate and intensive selection against rachii, Setaria sp. spikelets with rachillas and most probably also weeds. The byproduct cleanings were then swept into the burning context. But why were the Setaria italica crop seeds also being cleaned out? Most likely these seeds represent tail grains of Setaria italica that were selected out since their inclusion effects the quality of the final product and the food produced. The Panicum miliare seeds were either in that context (where they were disposed and got burnt with the Setaria italica) already through an earlier independent event or entered the context subsequently. Since no Panicum miliare spikelets with rachillas are present, it is argued that the same processing activity was not being performed on both the crops. It is likely that the Panicum miliare crop was being cleaned only for tail grains (i.e. the tail grains are often unsavory and could effect the quality of the ultimate food product).

The second reason for the seed pocket being more likely related to a latter stage of crop processing (rather than a roasting accident), is the presence of rachii, Setaria sp. spikelets with rachillas, and weeds. These components would not be present at the stage of roasting for the purpose of dehusking. As demonstrated in chapter 5, by the roasting stage the only component left in the product are crop seeds. All other components have already been processed/selected out. Therefore, one can strongly assert that the composition of the seed pocket is most indicative of a latter crop processing stage.

In summary, it is proposed that the Setaria sp. archaeobotanical assemblage at Babar Kot is indicative of crop cultivation and primary usage as human food. A secondary use as fodder is not negated, but with the given data this cannot be clearly demonstrated.

Cereal Rachis Fragments: A total of 41 rachis fragments were recovered at Babar Kot, of which 26 were from the seed pocket discussed above (Table 6-5). These rachii have been identified as those of Setaria sp. The rachii occur primarily in the slope units,and in significantly higher densities in features contexts (Table 6-8). In the mound units, the rachii occur in lower frequencies, and in equal densities in feature and non-feature contexts. This spatial distinction could be indicative of differential activity areas at the site, specifically the slope areas being the primary locales for crop and food processing.

Regardless of this spatial variation within the site, their significantly higher frequencies in feature contexts links them unquestionably to specific activities related to human behavior pertaining to crop processing for human food. Stratigraphically, rachii occur in significantly higher frequencies in Occupation III, in lesser frequencies in Occupation II and are absent in Occupation I (Table 6-7).

The cereal rachii are indicative of crop processing activities, and will aid in defining activities related to domestic food processing. In addition, they will be used to model the role and status of Setaria italica and millets in general at Babar Kot.

Linum sp.: 33 seeds were recovered and identified as an oilseed (Table 6-5). Initially they were tentatively identified as Sesamum sp. (Reddy n.p), but further detailed analysis disaffirmed that identification, and they are confirmed as belonging to Linum sp.. The seeds are identified as Linum sp., but their species is not certain. The oilseed can be grown as a cold or warm weather crop depending on the species. The crop is grown for the seed, and specifically to extract oil from it. Traditionally it was also grown as animal fodder.

These flat and ovate oilseed seeds recovered from Babar Kot are measurable and well-carbonized. The average measurements are summarized as follows: 3.03mm in

length and 2.45mm in breadth.

The oilseeds occur only in the slope units and in highest frequencies in the final strata of Occupation III (Tables 6-6, 6-7). They are primarily associated with feature contexts (Table 6-8), specifically in a Occupation III pit which also had animal bones and domestic refuge, other crop seeds, weed seeds and rachii.

The presence of Linum sp. seeds is important because it demonstrates that the inhabitants of Babar Kot were not totally concentrating their subsistence base on millet crops, but the oilseed was also part of their subsistence system. Whether they were extracting oil from the seeds or not cannot be conclusively demonstrated, however, the condition of the recovered oilseeds sheds some light on this issue. All the 33 oilseeds showed signs of rupture on the narrow end, which could be indicative of their being crushed for oil. However, this must remain speculation until ethnographic studies can confirm such morphological effects, or other patterns indicative of crushing these seeds for oil. However, it does remain an intriguing speculation with important implications on the issue of the breadth of the subsistence base at Babar Kot.

Legumes: Brassica, Lathyrus, Lens, Vicia

A total of 27 carbonized seeds have been identified as being leguminous, and they belong to the genera Brassica, Lathyrus, Lens and Vicia (Table 6-5). They occur in varying frequencies, and also demonstrate varying spatial and temporal distribution. Their presence further demonstrates that the Babar Kot inhabitants had a relatively broad subsistence base. In addition, the presence of Lathyrus sp. and Lens sp. indicate winter cultivation/procurement, since these crops are most often grown in cold weather.

Legumes occur in higher densities in the slope units as compared to the mound units (Table 6-6). In the slope units the legumes occur exclusively in feature contexts

(Table 6-8). Stratigraphically, Occupation I has the highest density of legumes, while occupations II and III have lower densities (Table 6-7).

Brassica: One seed was recovered which measured 2mm in diameter. This legume seed is rounded and in good condition, and has been tentatively identified as Brassica sp.. It occurs in a slope feature in Occupation III.

Lathyrus: One seed was recovered which is small and wedge shaped and measures 2.53mm in length and 2.32 in breadth. It has been tentatively identified as being Lathyrus sp.. This legume was recovered from a mound feature in Occupation II.

Lens: A total of 18 seeds of this legume were recovered and they dominate the legume assemblage. The grains are lenticular and compressed with a visible hilum scar, and a mean diameter of 2.08mm and a mean thickness 1.46mm. The Lens sp. seeds occur in higher densities in the slope units (Table 6-6), and exclusively in feature contexts there (Table 6-8). Occupation I shows the highest density of Lens sp. seeds (Table 6-7).

Vicia: A total of 7 seeds have been tentatively identified to be those of the legume Vicia. This is the second most frequent genus of the legume assemblage, and occurs in significantly higher densities in the slope features of Occupation III (Table 6-7).

Non-Crop Plants: A total of 17 different non-crop plant genera, termed weeds, were recovered from the site (Table 6-5). These occur in both areas of excavation, but in higher densities in the slope excavations (Table 6-6). Stratigraphically, Occupation

III has a significantly higher density (Table 6-7) of non-crop plant seeds.

The following genera were recovered: Aizoon sp. (4), Carex sp. (8), Cheno/Amrnathus sp. (3), Cyperus sp. (190), Digitaria sp. (210), Echinochloa sp. (14), Eragastis sp. (171), Ficus sp. (1), Lotus sp. (3), Medicago sp. (2), Phalaris sp. (2), Phyllanthus sp. (7), Polygonum sp. (11), Solanum sp. (3), Trianthema sp. (91), Urochloa sp. (396) and Zizyphus sp. (7).

The 17 different genera can be classified into the different weed categories developed in chapter 5. The resulting categorization reveals the presence of four weed types, dominated by the small free light weed (SFL) category that comprises 69% of the weed assemblage. The small free heavy (SFH) weed category comprises 30% while the small headed heavy category (SHH) and the big free heavy (BFH) weed category are infrequent, only representing 0.6% each. It is important to note that not all the weed categories are represented. The ethnographic modeling presented in chapter 5 has demonstrated that specific categories of weeds can be used as indicators of different stages of crop processing, and the categories present in the Babar Kot weed assemblage (SFL, SFH, SHH and BFH) will be used to shed light on what the archaeobotanical assemblage at the site is most indicative of: earlier processing stages or later processing stages. This information can be used to infer whether the crops were cultivated at the site or brought in through exchange from elsewhere.

Among all these weeds, Urochloa sp. occur in the highest densities, and constitute 35% of the weed assemblage. These weed seeds are minute, with distinctive markings on the surface. The other weeds which occur in relatively high proportions are Cyperus sp. (17%), Digitaria sp. (19%), Eragastis sp. and Trianthema sp. (8%). Stratigraphically, Urochloa sp., Digitaria sp. and Eragastis sp. predominantly occur in Occupation III, while both Cyperus sp. and Trianthema sp. occur in higher frequencies

in Occupation I and in lower frequencies in Occupation II and III (Table 6-7). Contextually, all five weed genera occur in significantly higher densities in feature contexts, with Eragastis sp. occurring exclusively in feature contexts (Table 6-8). Spatially, these weed genera occur in higher frequencies in the slope units, with Eragastis sp. and Urochloa sp. occurring exclusively in the slope units (Table 6-6).

The correlation of particular weeds to millets and legumes will be addressed in chapter 7. Weeds will be also used to identify activities and activity areas related to crop processing and food processing, since different characteristics of the weeds can be used to identify different stages of processing (Reddy 1991b).

Spatial Trends

Comparing the archaeobotanical data from the two excavations areas at the site, the slope and the mound, it is noted that there is a higher recovery of carbonized plant remains from the slope units per liter of sediment floated (Table 6-7, Figure 6-5). In other words, the density of carbonized seeds is significantly higher on the slope and this is reflected in higher densities for summer cultivars/millets, legumes and weeds. In both areas, summer cultivars have the highest densities followed by non-crops and then by legumes (Figure 6-5). The higher densities of carbonized seeds in the slope units could be related to context. There are more feature context samples from the slope units, and there may be a direct correlation between the context of the sample and the density of seeds recovered. This will be discussed in the subsequent sections.

There is some spatial differences in the particular crop plant genera recovered from the slope and the mound units. For example Eleucine sp. and Lathyrus sp., occurring in relatively low densities, were recovered only from mound units. Similarly Linum sp., Brassica sp. and Vicia sp. were recovered only from the slope units. Of

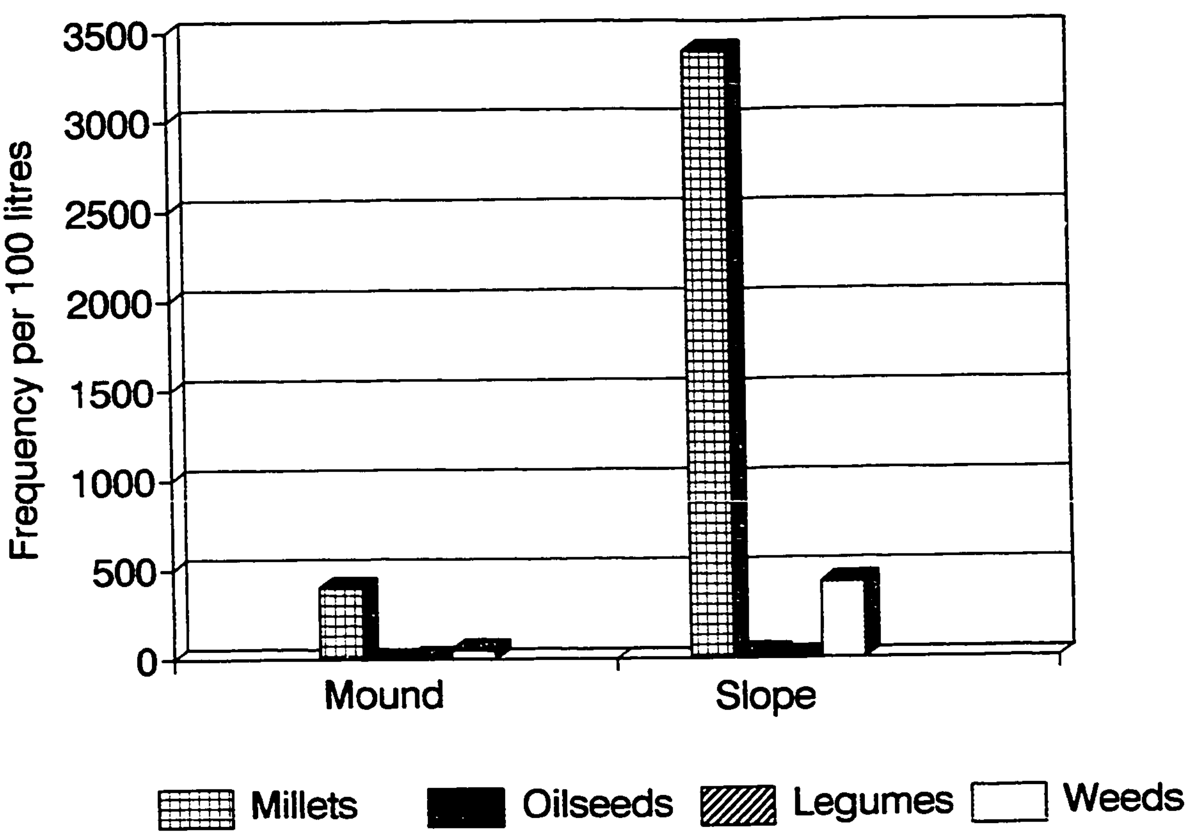


Figure 6-5. Babar Kot: Spatial Distribution of Millets, Oilseeds, Legumes and Weeds

these, both Brassica sp. and Vicia sp. occur in relatively low frequencies. Nonetheless it is important to note this spatial distinction.

A spatial variation which is very significant entails the presence of Setaria sp. spikelets with rachillas and Setaria sp. rachii in the slope units, but their prominent absence in the mound units (Table 6-6). These two components are used to identify crop processing activities, since they are processed out at specific stages (as discussed in chapter 5). Their explicit presence in the slope but not in the mound units, leads to unmistakable deductions regarding the spatial differentiation of various activities. The crop processing activities related to the selection/cleaning out of Setaria sp. spikelets with rachillas and the Setaria sp. rachii were being performed primarily in the slope areas during Occupation II and III (Table 6-6, 6-7). This issue will be addressed in further detail in chapter 7.

Another important spatial distinction occurs within the weed assemblage (Table 6-6, Figure 6-6). The weed assemblage from the mound is characterized by the dominance of SFL (Small Free Light) weeds and SFH (Small Free Heavy) weeds, and a comparatively low frequency of SHH (Small Headed Heavy) weeds. The slope weed assemblage, however, is primarily dominated by the SFH (Small Free Heavy) weeds, with SFH (Small Free Heavy) weeds occurring in significantly lower frequencies. In addition, the slope assemblage also has SHH (Small Headed Heavy) weeds and BFH (Big Free Heavy) weeds low frequencies but still more common than in the mound units (Figure 6-6). Thus, the slope units are dominated by SFL (Small Free Light) weeds along with crop plant spikelets with rachillas and rachii fragments. These associations and patterns are critical for the interpretation of crop processing activities, since different categories of weeds are processed out through specific processing stages. This information, coupled with the data on the distributions of Setaria sp. spikelets with rachillas and Setaria sp. rachii, will be instrumental for the identification of specific

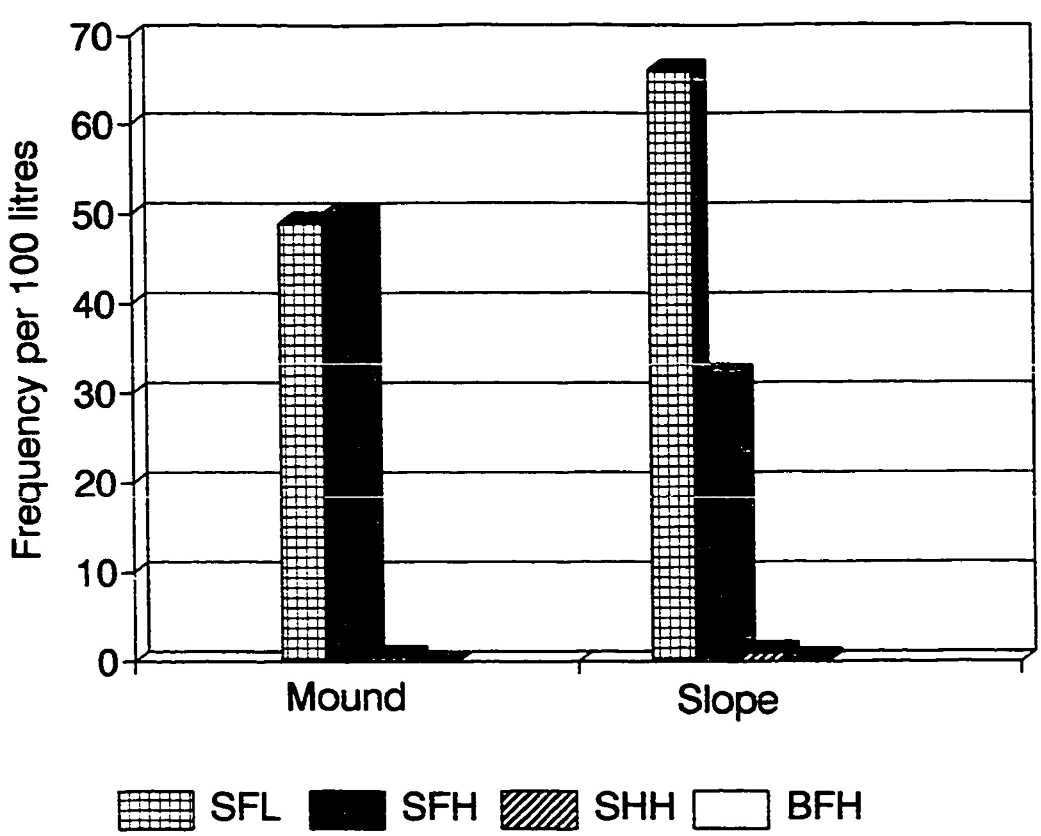


Figure 6-6. Babar Kot: Distribution of Weed Categories on the Mound and the Slope

processing activities.

Stratigraphic Patterns

There is considerable variation in the distributions of archaeobotanical remains recovered from the different occupational levels (Table 6-7, Figure 6-7). Occupation III has the significantly highest densities of carbonized seeds, and occupations II and I have lower and comparable densities. Occupation III also has the most number of feature contexts samples. Occupation II has relatively few samples from feature contexts, while Occupation I has none. The correlation of context and recovery of carbonized seeds will be considered in the next section.

Occupation I has the highest densities of legumes, and the second highest frequency of weed seeds (Table 6-7). The legume assemblage of Occupation I is exclusively represented by Lens sp., and the millet assemblage is represented only by Panicum miliare. The weed assemblage is represented equally by SFH (Small Free Heavy) and SFL (Small Free Light) weeds. Millets occur in densities similar to Occupation II but are represented only by Panicum sp.

Occupation II has the lowest density of carbonized seeds at the site, and also has the lowest frequency of weed seeds (Figure 6-7, Table 6-7). The millet assemblage is represented by two crops, Setaria sp. and Panicum miliare. Setaria sp. spikelets with rachillas and rachii occur in very low densities in Occupation II. The weed assemblage of Occupation II is dominated by SFL (Small Free Light) weeds, although SFH (Small Free Heavy) weeds are also well represented.

Occupation III has the highest densities of carbonized seeds in all the groups except legumes (Figure 6-7, Table 6-7). This last occupation has the significantly highest densities of millets and weed seeds. Among the millets, Setaria spp. dominates the assemblage, specifically Setaria italica. Rachii fragments and spikelets with rachillas of Setaria sp. are also recovered in relatively high frequencies. Legumes show a low

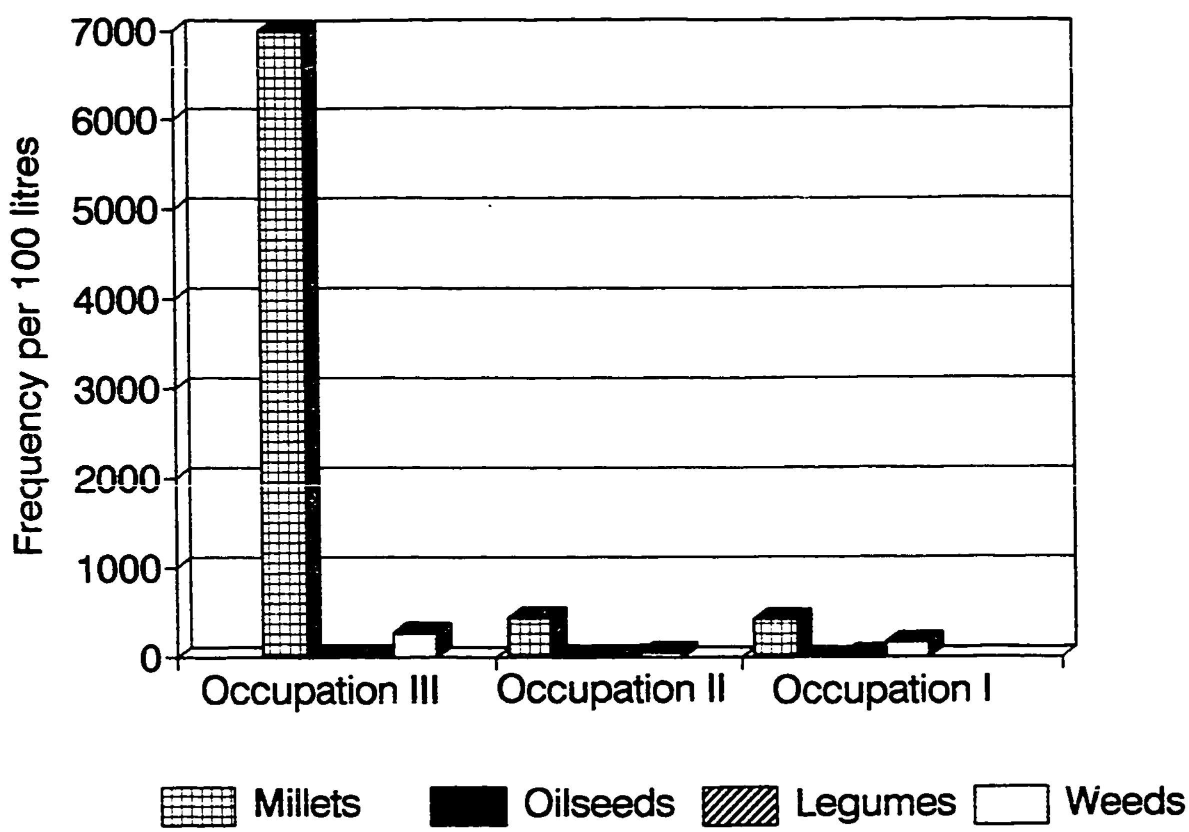


Figure 6-7. Babar Kot: Occupational Distribution of Millets, Oilseeds, Legumes and Weeds

density, although Linum sp. was recovered primarily in Occupation III. The weed assemblage of Occupation III is dominated by SFL (Small Free Light) weeds, although SFH (Small Free Heavy) weeds are also moderately represented. In addition, Occupation III weed assemblage also has SHH (Small Headed Heavy) and BFH (Big Free Heavy) weeds in low frequencies. There is clear change in the ratios of the different weed assemblage categories from Occupation I through III.

Contextual Relationships

Contextual inferences are significant because they shed light on the initial status of the plant material; in other words, the motive for their discard and primary use can be inferred from the context of their discovery. At Babar Kot, site there is distinctive contextual patterning of archaeobotanical remains. Feature contexts of the Babar Kot samples include the seed pocket, ash pits, burnt surfaces, distinctive features, and pot contents.

An important pattern discerned at Babar Kot is that the samples from defined feature contexts have a significantly higher density of carbonized seeds in contrast to samples from general fill sediments (Figure 6-8). This trend is distinct from the patterns observed at Oriyo Timbo where samples from feature contexts with high temperatures (such as hearth samples and tandoor fill contents) had the lowest frequency of carbonized seeds, while samples from deposits above and below features were noted to have the highest frequency of carbonized seeds.

Additionally, the high density of seeds at Babar Kot is primarily associated with burnt soil rather than with high quantities of charcoal. This association is similar to the pattern of archaeobotanical recovery at the site of Oriyo Timbo where the contexts with high quantities of charcoal appeared to have the lowest frequency of carbonized seeds (Pearsall 1989; Reddy 1991b: 81). These variations and similarities demonstrate that

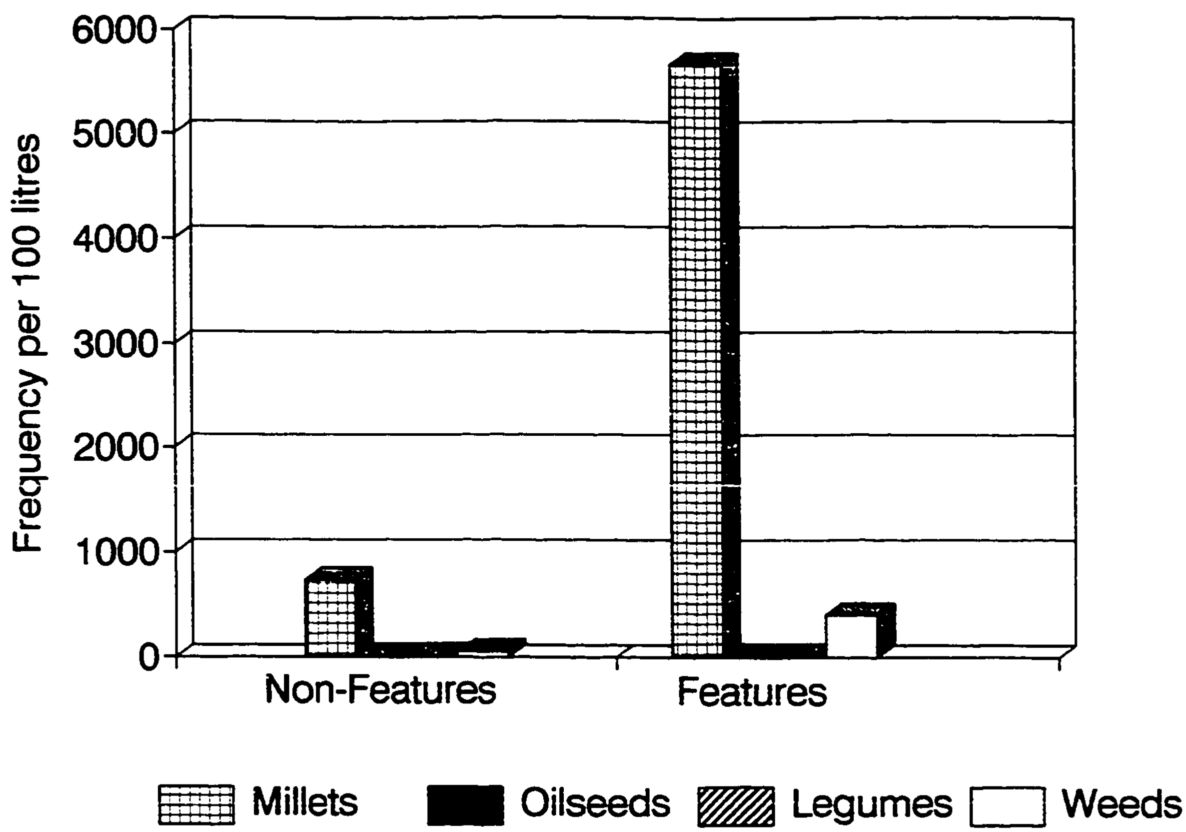


Figure 6-8. Babar Kot: Contextual Patterns of Millets, Oilseeds, Legumes and Weeds

the collection of sediment samples for flotation should be systematic at all sites and contexts, and in addition reiterate the need for the paleoethnobotanist to participate in the excavations.

The densities of carbonized seeds recovered from the slope units is in general (regardless of contextual distinctness) significantly higher than the carbonized seed densities on the mound (Figure 6-5, Table 6-6). One of the contributing factor for this spatial discrimination is context, that is distinct features caused by human behavior and activities. Two patterns in the data support this argument. The first relates to the higher densities of carbonized seeds in specific feature context samples. In addition, there are more feature context samples from the slope units. Thus, given these two observations it is argued that there is a direct correlation between the context of the sample and the density of seeds recovered. In other words, the intentional discard of seeds into features is occurring in greater frequencies than the incorporation of seeds into the general occupation deposits.

The densities of features clearly vary stratigraphically between the three occupations. Occupation III has the most number of features, accounting for 74% of the total features excavated. Occupation II has 26% of the features excavated, while Occupation I contained no features. It is very important to note that the densities of carbonized seeds recovered also follows this succession, with Occupation III having the significantly highest density of carbonized seeds recovered (Table 6-7, Figure 6-7).

Different plant species recovered at the site appear to be differentially associated with specific feature contexts (Table 6-8, Figure 6-8). Among the millets there is a definite variation in contextual recovery. For example, Eleucine coracana is differentially correlated to context, occurring specifically in the non-feature contexts (occupation deposits not clearly associated with any particular activity such as food preparation). The contexts of Eleucine sp. recovery relate to an amalgam of activities

related to human occupation and subsistence, and not to a specific activity. What this suggests is that Eleucine sp. cannot be explicitly linked to human usage. Earlier in this chapter, the presence of these carbonized seeds, albeit in low frequencies, was explained as being a result of three possible activities: crop processing, low usage of this particular crop or use as green fodder. However, it was stressed that the presence of carbonized seeds negates the use of the species solely as fodder. It is likely that it was used as a fodder in addition to being used as human food. Nonetheless, the low densities suggest lower usage as compared to the other millets recovered from the site. The presence of Eleucine sp. seeds can also be explained through two separate processes (if one assumes that the plant was not being used as fodder and food). The seeds of this plant could have been brought in as part of an assemblage of plants gathered for different purposes or was present in sod which was burnt as fuel (Pearsall 1988:100). I argue that even though the last two scenarios are plausible, it is more likely that the crop was being used as fodder and food. It is evident that the usage was limited (based on the significantly low density of seeds recovered at the site), and it appears to have been of secondary importance as a food plant.

Typically Setaria italica and Panicum miliare occur in significantly higher densities in feature contexts than in general deposits, thus linking them unquestionably to specific human activities (Table 6-8, Figure 6-9). For example, about 90% of the Setaria italica seeds were recovered from feature contexts in the slope units, and about 75% of the Setaria italica seeds were recovered from the feature contexts in the mounds. The Setaria italica spikelets with rachillas also occur in significantly higher densities in feature contexts. These higher densities in feature contexts appear to reflect human activity residues and discards related to crop processing and food preparation. The features are a direct link to these activities, providing an inverse picture of the

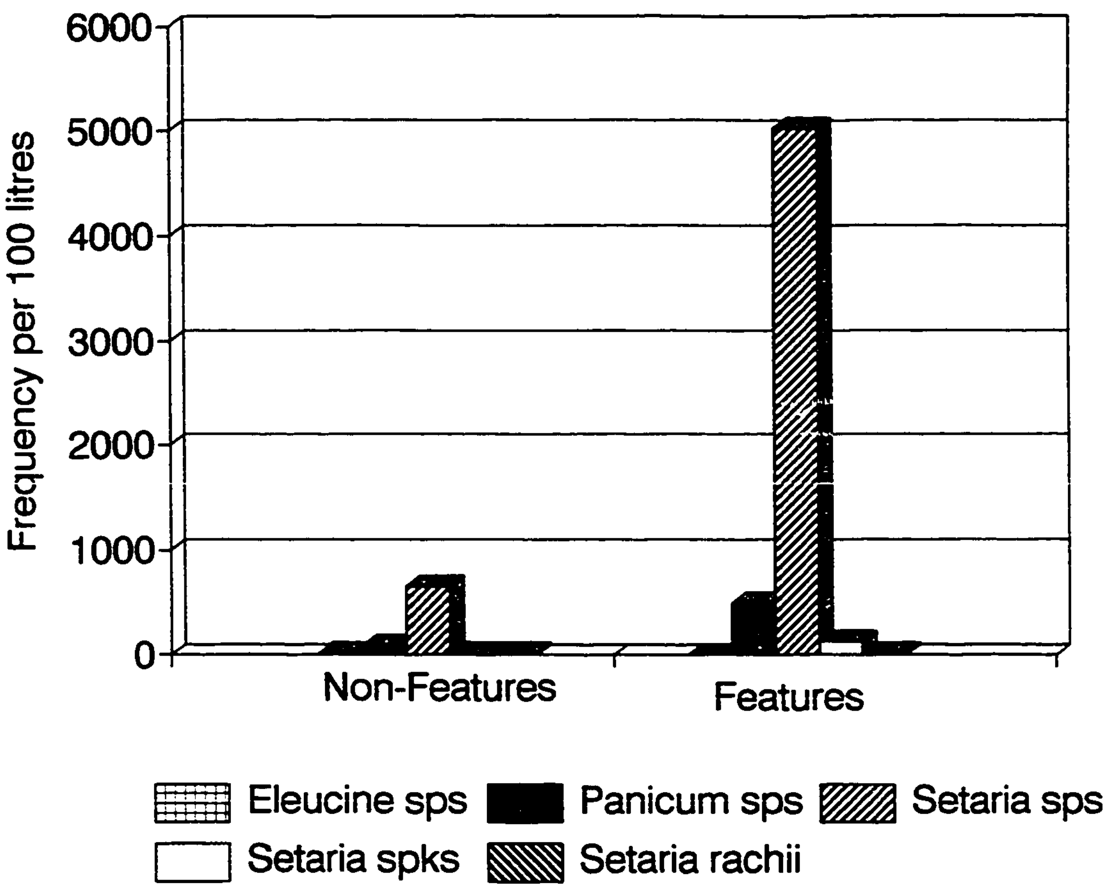


Figure 6-9. Babar Kot: Contextual Patterns of Various Millets

activities, which can be reconstructed using ethnographic data.

Contextually, the five major weed genera (Urochloa sp., Cyperus sp., Digitaria sp., Eragastis sp. and Trianthema sp.) occur in significantly higher densities in feature contexts, with Eragastis sp. occurring exclusively in feature contexts (Table 6-8, Figure 6-8). This pattern indicates that the presence of Eragastis sp. seeds is a result of a specific human activity and they are not non-cultural intrusives.

The different weed categories occur differentially based on context, suggesting that there is a relationship between context and the weed category. The weeds of the BFH (Big Free Headed) and SHH (Small Headed Heavy) categories occur exclusively in feature contexts, thus connecting them to human activities. Weeds of SFL (Small Free Light) and SFH (Small Free Heavy) categories occur in both feature and general occupation deposits, but they occur in significantly higher densities in feature contexts. The implications of this patterning is explicit in that it is highly probable that the presence of the weeds is a result of specific human behavior and activities related to crop processing and food preparation.

Another plant that shows contextual patterning is Linum sp., and similar to the Setaria spp. and the Panicum sp., these oilseeds have a significantly higher density in feature contexts, specifically in an Occupation III pit on the slope. This particular feature pit has a relatively high density of carbonized seeds (1094 carbonized seeds in 28.5 litres of sediment), along with animal bones and other domestic refuge such as burned ceramics, clay lumps and ash. The general sediment of the pit was burnt and ashy, and the pit is interpreted as being used as a trash dump with a series of disposal episodes.

Carbonized seeds recovered from this dump/trash pit include millets seeds (Panicum sp., Setaria sp. and Setaria rachis fragments), legumes (Lens sp., Vicia sp. and Brassica sp..), and a range of weeds. Among the weeds, the category significantly

represented is that of the SFL (Small, Free, Light) accounting for 64% of the weed assemblage. Small Free Heavy (SFH) weed seeds occur in lower frequencies accounting for 34% of the weed assemblage in the pit, while SHH (Small Headed Heavy) weeds account for only 2% of the assemblage.

The pit was excavated in four levels, and there is a distinct pattern to the archaeobotanical remains recovered from the different levels. The bottom level of the pit has a low density of carbonized seeds (0.2% of the total carbonized seed assemblage of the pit) with only 2 seeds of Setaria italica. The middle two layers of the pit accounted for the majority of the assemblage with 79% of the seeds. The assemblage of these middle layers is mainly dominated by Setaria sp., although Urochloa sp. also occurs in relatively high densities. Linum sp. occurs in significantly higher densities in these middle levels, as do the Setaria sp. rachii. The top level of the pit is characterized the presence of Panicum sp. and Setaria sp. in equal proportions. Legumes occur exclusively in this upper layer of the pit.

The stratigraphic variation of the different plant remains in the pit is very significant, because it is indicative of sequential dumping episodes, and also the differences in the dumping contents during each episode. The argument for sequential dumping (as opposed to one episode) is based on two lines of evidence. First, the relatively deep pit stratigraphy reveals a sequence of distinct ashy gray layers representing different episodes of dumping. Second and equally important is the wide range of plant remains recovered from the pit. If it was a single episode of dumping, then it is more likely to have a very limited range of genera/species perhaps only one or two, since different plants are not processed for food at the same time and mixing of the genera typically would not occur. Thus, the wide range of plants recovered, the stratigraphic variation in the pit, and the patterned variation in the distribution of

different species between levels, are all indicative of a series of dumping episodes.

Based on the patterning of the recovered archaeobotanical remains in the pit, it appears there was more dumping of plant remains initially, which decreased over time. This is based on the very high densities in the middle two layers and the low density of carbonized seeds in the top layer of the pit. As noted before, there was a distinction in the disposal contents during the different dumping episodes. The first dumping episodes in the pit involved the disposal of high numbers of seeds and rachii of Setaria sp., seeds of Linum sp., and a range of weeds of which the SFL (Small Free Light) and SFH (Small Free Heavy) are dominant. The later dumping episodes involved the disposal of Panicum sp., Setaria sp. and importantly the discard of legumes.

The interpretation of this assemblage (of the entire pit) as it relates to crop processing and/or food preparation is significant. Two main interpretations are offered to account for the presence of the assemblage; cleanings (or spillage) from crop processing stages or incorporation from fodder into the dung fuel. In both of these cases the seeds were carbonized before entering the pit context, most likely in a hearth (given the presence of burnt ceramics and ash) which was subsequently cleaned out and dumped into the trash pit. Of the two explanations the first is more plausible, mainly because of the high density of seeds recovered in the pit which is unlike a dung fuel assemblage (Miller 1984). However, it is quite likely that crop processing byproducts could have been fed as fodder and subsequently the dung from the animals (along with undigested seeds) was used as fuel. Therefore, both the explanations are feasible, that the assemblgae is indicative of cleanings from crop processing or incorporation as fodder into dung which was later used as fuel.

Other features excavated at the site and sampled for archaeobotanical remains also have high densities of carbonized seeds. The most impressive feature recovered at Babar Kot is the seed pocket of Setaria sp. which was discussed earlier in the chapter.

Other important features which yielded archaeobotanical materials include pot contents from Occupation III on the mound, a distinctive Occupation III ash pit on the slope, an Occupation II pit on the mound, and a distinctive Occupation II clay feature on the mound.

The contents of a Late Harappan pot discovered in Occupation III on the mound, were floated for archaeobotanical materials. The carbonized seeds recovered include 79 caryopsis of Setaria italica and 2 Digitaria sp. seeds. A high percentage of the Setaria sp. seeds are cracked, but diagnostic. The pot was not sealed, and thus it is possible that the presence of the carbonized seeds in the pot contents could be a result of post depositional processes. For this purpose, the archaeobotanical contents of adjacent samples were examined. The archaeobotanical remains from the adjoining samples are comprised predominantly of Setaria sp. caryopsis, with Eleucine sp., Setaria sp. rachii and Trianthema sp. occurring in low frequencies. The Setaria sp. seeds from these adjoining areas are also cracked but diagnostic. It is important to note, however, that the general deposits of the level in which the pot was located, have relatively low densities (4 seeds per liter), while the pot contents have a significantly higher density of 81 carbonized seeds in 0.75 liter (101 seeds per liter). The significantly higher density in the pot is an indication that their presence is not due to post depositional processes. If the carbonized seeds infiltrated the pot through post depositional processes, then a similar density of carbonized seeds would be expected from the surrounding deposits.

Therefore, if one concedes that the seeds are truly the original pot contents, then the question of carbonization arises since in a majority of archaeological examples seeds stored in pots are not burned or carbonized and hence will not survive. Why were the seeds burnt/charred and then stored in the pot? Setaria sp. seeds have hard glumes

and need to be dehusked before consumption. Often before dehusking, the crop seeds are roasted to loosen the husk and facilitate efficient dehusking. The storage of seeds is most effective (in terms of loss to pests and bacterial/fungal damage) before dehusking. One explanation for the carbonized seeds being stored in the pot is that the Setaria italica seeds were roasted for dehusking, and accidentally some were over charred. They were then dehusked through pounding activity and this is supported by the cracked nature of the seeds, and then subsequently stored in the pot for consumption. The storage of seeds after dehusking/pounding is a positive indicator that their consumption was planned for in the immediate future, and they were not being stored for the long term or for trade/exchange.

Another feature of considerable interest is an ash pit on the slope in Occupation III. The pit consists of loose ashy deposits with pockets of charcoal concentrations, burnt bone and ceramic fragments. One side of the pit was dug into an adjacent stone wall of Occupation III. The nature of the deposits (presence of burnt bones etc) suggests that the pit contents are domestic refuse and cleanings of areas related to possible cooking fires, as noted by the burnt bones. The dumpings could have been cleanings or residues of food preparation and consumption. Additionally, the cleanings could also include the residues of dung fuel from the hearth, thus the seeds being more indicative of fodder rather than human food. The high weed seed densities is indicative of such an activity, though it is equally likely that the crop processing byproducts could have been fed as fodder and subsequently the animal dung (and its undigested seeds) used as fuel. The pit was excavated by the author and a series of ashy dumpings (as opposed to one episode) were observed.

The pit was excavated in several layers to facilitate stratigraphic differences. The densities of archaeobotanical remains from the lower layers of the pit are significantly higher than the upper layers. There is, however, no distinct pattern in the

distribution of the various plant remains. The archaeobotanical assemblage of the pit is dominated by weed seeds (accounting for 60%) and millets (accounting for 35%). Legumes occur in low frequencies (5% of the assemblage) and are represented by Vicia sp. and Lens sp., although Vicia sp. occurs at a significantly higher frequency. The millet assemblage is predominantly represented by Panicum miliare. Among the weeds recovered from the pit, three weeds dominate the assemblage, Urochloa sp. (41%), Digitaria sp. (26%) and Trianthema sp. (21%). Two weed categories dominate the weed assemblage, those of SFH (Small Free Heavy) constituting 51% and the SFL (Small Free Light) category constituting 49%.

Two pits excavated in units on the mound were studied for their archaeobotanical remains. The contents of the two pits are distinct in that one pit is dominated by Panicum miliare and the other pit is dominated by Setaria italica. The pits are spatially distinct even though they are both in Occupation II. The sediment of both the pits was ashy dark gray brown with moderate amounts of charcoal. The pits are most probably related to domestic dumping and cleanings rather than dung fuel because of the high ratio of crop seeds to weed seeds. Miller (1984) argues that dung fuel contexts yield higher densities of weeds versus cultigens. The pit dominated by Panicum miliare (75%) has only 2 other archaeobotanical plant remains in the assemblage, that of Cyperus sp. (21%) and Trianthema sp. (4%). In contrast, the pit dominated by Setaria italica (48%) has more heterogeneous assemblage with 5 other archaeobotanical components; Setaria sp. rachii fragments (2%), Lens sp. (2%), Aizoon sp. (2%), Cyperus sp. (6%), Trianthema sp. (2%) and unidentifiable seed fragments (40%). This patterned variation between the two pits is indicative of differential processing pertaining to the two crop plants which will be addressed in the next chapter.

The last feature discussed is a Occupation II clay feature excavated in one of the mound units. The clay feature is semi-spherical, set in the ground with slightly raised and distinct walls. The ashy sediments from this clay feature were floated for archaeobotanical remains. The sediments consisted of heavy clay clumps (most are probably the collapsed walls of the feature) and pottery fragments. The archaeobotanical assemblage is dominated by carbonized seeds of Setaria italica (60%). The other components of the assemblage occurring albeit in low frequencies, are Panicum miliare (5%), a Setaria sp. rachis fragment (0.4%), Lathyrus mungo sp. (0.4%), Lens sp. (0.4%), Echinochloa sp. (0.4%), Trianthema sp. (2%) and unidentifiable seed fragments (30%). Although the nature of this feature is uncertain, it is probably a form of hearth (ethnographic and prehistoric examples of similar hearths occur in the Near East).

An important observation in the contextual patterning of the archaeobotanical materials of Babar Kot is that there is a distinct specificity of Setaria italica and Panicum miliare to different pit features. Only one millet dominates the contexts of a pit and this indicates a specificity of activities pertaining to these two different millets. Therefore, only one of the two millets is being utilize dominantly in particular locales based on the evidence from pit features. A subsequent implication is that the two plants were treated as separate plant crops, albeit of varying degrees of importance. This has important implications for the reconstruction of the subsistence economy at the site, since more than one crop was being utilized as a food crop.

Summary

The Babar Kot 1990-91 archaeobotanical investigations has revealed excellent archaeobotanical preservation and a high concentration of carbonized seeds per liter of sediment floated. There are several conclusive statements that can be made about the

Babar Kot archaeobotanical assemblage, most notably there is a strong evidence of summer and winter crops. The summer crop of Setaria italica dominates the crop assemblage at Babar Kot, and this is similar to the site of Rojdi Phase C (Weber 1991). Rachis remains of Setaria sp. were also recovered at Babar Kot and Rojdi. Rachis remains are strong indicators of active crop processing stages and this may imply that the crop was grown nearby rather than being traded in from other areas (Hillman 1981). It is interesting to note these similarities between the two sites with respect to the role of millet cultivation in the subsistence economy of the region. The implications of these patterns will be discussed in the subsequent chapter taking into consideration several variables which need to be accounted for (including recovery procedures, identification and the nature of the sites).

Several implications of the archaeobotanical results from the site of Babar Kot are evident. Summer cultivars are a very important and comprise a significant part of the archaeobotanical assemblage. These include 'millets' which dominate the assemblage throughout the occupation. In a majority of the cases, the millet crops of Eleucine sp., Panicum sp. and Setaria sp. are not grown in the winter months in the present-day agricultural system of Northwest India. On the other hand, the legumes Lathyrus and Lens are generally winter season crops. The legume seeds, however, occur in low frequencies and their use was probably limited. Therefore, it can be reasonably inferred that most of the subsistence cultivation was occurring in the summer monsoonal months, and limited cultivation in the winter months. The two major millet crops (Panicum miliare and Setaria italica) recovered from Babar Kot appear to have been cultivated by the occupants in the vicinity of the site. Several non-crop plants in the assemblage (such as Digitaria sp., Medicago sp., Phyllanthus sp., Trianthema sp. and Urochloa sp.) are weeds that grow wild in millet fields and are

good fodder for cattle. The associations and implications of such weeds in relationship to the crop processing activities of Panicum miliare and Setaria italica will be addressed in the next chapter.

Analysis of the archaeobotanical assemblage at Babar Kot also revealed spatial, stratigraphic and contextual patterning. There are is very distinct spatial differences in the archaeobotanical materials, with the slope units containing overall higher densities of carbonized seeds. There are spatial differences with respect to specific plants, with some only being recovered from the slope or only from the mound. The most significant spatial pattern is that the Setaria sp. spikelets with rachillas were recovered only from the slope units. This pattern is indicative of specialized activities related to food processing on the slope area and the prominent absence of such activities in the mound units.

Stratigraphically, later Occupation III has the highest densities of carbonized seeds. There is also an important association of carbonized seeds in significantly higher densities in feature contexts as opposed to general fill deposits throughout the occupation at the site. This association with feature contexts is particularly important because the seeds are indicative of specific human behavior and activities related to site maintenance and cleaning reflective of crop processing and food preparation.

Determining whether the millet plants were used as fodder or not is a complicated issue, and other lines of evidence are needed to fully address the question. The role of millets as cattle fodder at Babar Kot can be tested through carbon isotope analysis of the bone collagen (Reddy 1991b), and this application will be explored in the next chapter.

SUMMARY OF THE ARCHAEOBOTANICAL RESEARCH

There is strong evidence for the use of summer crops at both Oriyo Timbo and

Babar Kot. There are significant differences in the temporal, spatial and contextual patterning of the frequencies of carbonized seeds recovered at the two sites.

The archaeobotanical assemblage at Oriyo Timbo is dominated by weeds, although the millet seeds also occur in strong densities. Additionally the Oriyo Timbo archaeobotanical assemblage consists primarily of plant seeds, and have no rachii or any other plant parts. The absence of rachii suggests that the lower processing stages were not practices at the site (or at least in the areas excavated). Their presence would have been an indicator of lower levels of crop processing, and of cultivation at the site (see chapters 5 for full discussion of this issue). Thus given the nature of the assemblage and the lack of storage heaps or facilities, and the high proportions of weeds to summer crops, it is hypothesized that the cultivation of summer crops was not a major activity near the site.

The Babar Kot 1990-91 archaeobotanical assemblage is indicative of both summer and winter crop cultivation, with the summer crop of Setaria italica dominating the crop assemblage at Babar Kot. Setaria sp. rachis remains were also recovered and they are strong indicators of crop processing stages. This may imply that the crop was grown nearby rather than being traded in from other areas (Hillman 1981).

It is interesting to note the differences between the two sites with respect to the role of millet cultivation in the subsistence economy of the region. The implications of these patterns will be discussed in the subsequent chapter taking into consideration several variables which need to be accounted for (including recovery procedures, identification and the nature of the sites).

In conclusion, archaeobotanical remains provide significant data to study past economy and subsistence systems. It is nonetheless important to realize the limitations of this data set, mainly in controlling for factors of deposition, preservation and

recovery. Study of the archaeobotanical data sets from Oriyo Timbo and Babar Kot have revealed that carbonized plant remains have several qualities that make them highly valued archaeological evidence. Once the limitations are realized and the attributes complemented by other relevant sources of data, such as ethnographic crop processing and farming studies as done in this study, then fresh issues can be explored.

CHAPTER 7

ARCHAEOLOGICAL APPLICATION OF THE MODELS

INTRODUCTION

In order to link the archaeobotanical remains to past human agricultural activities it is imperative to delineate and distinguish the predepositional and depositional processes (Jones 1987). The main focus of this research project is discerning the predepositional processes related to crop husbandry and crop processing sequences from harvest to use as food, fodder or both. To discern the depositional processes, analytical and interpretive attention is focused on identifying and modeling the contexts in which preservation through charring of the plant remains (accidentally or intentionally) may most likely occur, and the subsequent human behavior related to the discard of these materials.

At the analytical level (chapters 5 and 6), specific methods were applied to identify patterns in the ethnographic and archaeological data and evaluate their significance. In this chapter, interpretive theory (based on the ethnographic modeling of chapter 5) is used to assign behavioral meaning to the patterns observed in the archaeobotanical assemblages, and it is also used to evaluate the relative merit of a series of possible interpretations.

Hypotheses and models of predepositional processes (specifically crop harvest and processing sequences), based on ethnographic observation, were presented in chapter 5. In this chapter, these hypotheses are tested against the archaeobotanical materials from Oriyo Timbo and Babar Kot. If patterns in the archaeological samples fall within the range of variation of the pattern of physical traces which resulted from a particular ethnographic activity (as summarized in the ethnographic models), one can then infer that a valid analogy exists. The degree of probability cannot be measured,

but the strong correlation of the two patterns is indicative of a viable analogy. The correlation between the two patterns can be further strengthened by evaluating the merits of several other possible interpretations that may have created such a pattern in the archaeobotanical data. In other words, this process entails defining, limiting and accounting for other factors which could have caused related patterns in the archaeobotanical data. Such testing of multiple hypotheses in the application of ethnographic models to the archaeological data greatly strengthens inferences and reduces concerns about the weakness of direct analogy. In addition, since the archaeobotanical application of ethnographic models is based primarily on the physical characteristics of the distinguishable components (such as weeds, rachillas and crop grain), it is not necessary that every species in an archaeological assemblage be present in an ethnographic study to make this comparison valid and informative.

The structure of this chapter consists of an initial discussion of the key factors involved in the archaeological modeling, and then the archaeological application of the ethnographic models is presented.

ARCHAEOLOGICAL APPLICATION OF ETHNOGRAPHIC MODELS

Application of the Models

As presented in chapter 6, the archaeobotanical assemblages from Oriyo Timbo and Babar Kot are significantly different in their compositions, nature, context and recovery rates. The Oriyo Timbo archaeobotanical assemblage consists primarily of seeds of the summer crops Eleucine sp., Setaria spp. Panicum miliare and Phaseolus mungo. In contrast, the archaeobotanical assemblage of Babar Kot is comprised of seeds, rachii and spikelets of crop plants Eleucine sp., Panicum sp., Setaria spp.,

Linum sp. and Legumes. The contextual, spatial and stratigraphic patterning of the archaeobotanical materials within each site is also significantly different. Thus, the different parts of the ethnographic models are applied separately to the two archaeobotanical assemblages. The questions posed for each archaeobotanical assemblage, however, are similar: Were the crops cultivated at the site or nearby, or were they brought as grain from other locals? If the crops were being cultivated, was it a primary subsistence activity, or were there other major subsistence activities such as herding cattle. If cattle herding was also an important subsistence practice, what effect might seasonal migrations and pastoralism have on crop husbandry practices ? Finally were the millets used primarily for human food, animal fodder or both?

Therefore, the archaeobotanical investigations at the two sites focused on addressing the economic importance of millet cultivation, and the final objective of the paleoethnobotanical study is to present a working model for the economic importance of the millet crops (Setaria spp., Panicum sp. and Eleucine sp.) in the subsistence system at Oriyo Timbo and Babar Kot. The interpretation of the archaeobotanical assemblages as being more representative of a food like or fodder like assemblage or both, is presented in this section.

To address whether crops were cultivated at each site by the occupants or brought in from elsewhere, the Oriyo Timbo and the Babar Kot archaeobotanical assemblages must have characteristics of particular crop processing stages that are indicative of these two distinct situations. For example, if crops were cultivated by the site occupants then it is highly probable that the lower processing stages of sieving and winnowing I occurred on site. In addition, if the cultivation was in the close vicinity, then one can expect (though it is not necessary) that some of the other lower processing stages (such as threshing and raking) also occurred at the site.

In contrast, if the occupants were bringing in the crop grain from elsewhere

(i.e., they are not cultivating the crops but obtaining them through trade and exchange, or, they were growing them elsewhere and bringing them to this site in the form of highly processed grain, as a part of a seasonal round), then it is very unlikely that any lower processing stages would be observed at the site; instead, only the highest processing stages (such as pounding, winnowing II and grinding) will be observed. This is because the crops are traded most often after their lower processing, particularly after the sieving stage but before the pounding stage. Thus, it is necessary to first correlate the Oriyo Timbo and Babar Kot archaeobotanical assemblages to the lower or the higher processing stages (and therefore most comparable to a situation when crops are brought in from elsewhere or cultivated by the inhabitants). Then the presence or absence of other possible factors (related and unrelated to crop processing) which could produce similar situations must be addressed. Once this question is answered, then the status of the millet crops (whether they were used primarily as human food or animal fodder) and the economic importance of millets for the Oriyo Timbo and Babar Kot inhabitants can be addressed.

The key characteristics of the lower processing stages and higher processing stages distinguished in the ethnographic study of Type B crops need to be reiterated (see glossary for term definitions, and chapter 5 figure models and tabulations). Specific emphasis is placed on Type B crops because the millets recovered at Oriyo Timbo and Babar Kot (Eleucine coracana, Panicum miliare and Setaria italica) are all Type B crops whose harvests are most likely to resemble a Type II harvest. These Type B millets are processed similarly through all the stages from harvest to the final cleaning stages with the primary differences entailing how the grains are prepared for consumption. The lower processing stages include harvest (Type II method), threshing, raking, sieving and winnowing I. Threshing and raking occur in the fields

predominantly, and hence it is unlikely that their residues will be preserved or discovered archaeologically. Whether sieving and winnowing I occur more often at the home bases is dependent on several factors including the efficiency of threshing and raking, the state of the crop at harvest (dry or fresh), distance of the fields from the home bases, and the availability of labor. It is important to note that even if sieving was done at the fields, it is very often repeated at the home base immediately before the winnowing I process. Since they all are small grained seeds, winnowing by wind is not appropriate, and the processing is primarily winnowing by shaking for the separation of the chaff, straw and other larger light materials.The key characteristics of these lower processing stages of a Type B crop (as identified in the models presented in chapter 5) include straw, chaff, panicle heads, rachillas (of all kinds), spikelets and grain with husk and weeds of all categories.

The higher processing stages of a Type B crop include the final winnowing I process, pounding, winnowing II by shaking, grinding and food preparation. These stages are necessary in the processing of all Type B crops. These processes are in certainty done in the home bases, and therefore are more likely to be discovered archaeologically. As in the case of sieving, winnowing I is repeated immediately before pounding; however, the byproducts of the final winnowing I by shaking are predominantly comprised of undesirable crop grains and weeds (rachillas are processed out predominantly in the initial phases of winnowing I). The key characteristics of the higher processing stages of a Type B crop (as identified and presented in chapter 5) include crop grain with husk and without husk, and weeds of SHH (Small Headed Heavy), SFL (Small Free Light) and SFH (Small Free Heavy) categories. The crop products in general are cleaned of all the non-crop grain components (such as rachii, rachillas and weed seeds) in the winnowing I by shaking stage. Grain without husk after the pounding stage include a relatively high percent of cracked grains.

Storage of these Type B crops (Eleucine coracana, Panicum miliare and Setaria italica) grain is widespread ethnographically. In the majority of cases fresh grain is seldom used as food, but has to be stored for some months before it is considered suitable for utilization. Consumption preference typically is given to grains that are older rather than fresh grain, mainly because of the enhanced cooking quality of stored grains. Customarily, storage and trade/exchange occurs after winnowing I and roasting (since the grain stores better with a decreased risk of fungal infections). This pattern is archaeologically significant since storage increases the probability of discovery, and roasting prior to storage often results in burning some grains which further increasing the probability of survival. When crop grains are stored before utilization (as compared to immediate use) there is a higher chance that they will be exposed to accidental burning. Additionally, since the storage is typically in domestic areas (rather than in the fields which are harder to discover archaeologically) their discovery is further enhanced. (See the model figures 5- 6, 5-7, 5-9, 5-11 for fire indices and ranking of different stages and locations: in the fields and home bases).

When Type B crop grain are most likely to enter the trade and exchange network can also be predicted and archaeological correlates identified. When the crop products enter the market is dependent on several factors including demand for the particular grain, labor involved to continue the processing, distance to market and nature of the grain (whether it would hold up better in a husked or dehusked state). Ethnographic information gathered during this study indicates that for village communities grains of crops such as Panicum miliare, Setaria italica and Eleucine coracana, enter the market system after several different stages of processing. It is important to focus on modern village level practices to model for the Harappan subsistence systems, since they are more analogous than the larger 20th Century market

systems. Crop grains are often traded locally and non-locally immediately after winnowing I by shaking in the modern villages of Gujarat and Andhra Pradesh. At this stage the assemblages are devoid of all the larger non-crop grain components such as large rachii, panicles, straw and large weeds but often still have some rachillas and small sized weeds. In some cases, marketing of crop grains is also done after the roasting, pounding and winnowing II stages, since roasting in the husked state aids the grain storage due to decreased exposure and likelihood to fungal attacks. At this point the grains have been dehusked and cleaned of all the chaff dust from the pounding stage, and the crop products are comprised only of crop seeds. Ground flour, the final product of the processing stages, is traded and exchanged only in rare cases.

The archaeobotanical crop seeds recovered from the two sites are direct indicators of specific losses that occurred at various stages of crop processing, mostly post harvest processing. This project's ethnographic study shows that crop grain losses can occur at harvest (through shattering of grains when a crop is harvested well after maturity - as seen in the 'Opportunistic' cultivation study and also at various post harvest processing stages (see chapter 5). The magnitude of loss is primarily dependent on the particular processing stages, the method of processing and the type of grain. Post harvest processing losses particularly those that occur in the home bases (see figure models of chapter 5) are of primary relevance to archaeologists since their preservation and discovery is high. This issue is discerned in further detail in the application of the ethnographic models to interpret the archaeobotanical assemblages of Oriyo Timbo and Babar Kot.

The analytical focus of this chapter entails discerning different crop processing activities that existed in the past through the application of ethnographic models to archaeobotanical patterns. In this context explicit emphasis is placed on the distinguishing cultural transformation of the archaeobotanical record. Cultural

transformations that effect the archaeobotanical record have been discussed eloquently by Miksicek (1987:224-230). Building on Shiffer (1976), and also Rathje and Shiffer (1982), he articulates archaeobotanical remains that are characteristic of de facto, primary and secondary refuse. De facto refuse include usable paleoethnobotanical materials abandoned in an activity locus such as seed caches; primary refuse entails trash discarded at the location of use such as seeds recovered from cooking pits, and secondary refuse consists of trash deposited at some location other than the location of use, and this includes the vast majority of plant remains recovered from archaeological sites (Miksicek 1987). In the following section contextual patterns at the two sites will be discerned in terms of these cultural transformations.

Oriyo Timbo

To reiterate the results of chapter 6, the archaeobotanical assemblage from Oriyo Timbo consists of millet and legume crop seeds, and non-crop seeds (weeds), of which the non-crop/weed seeds occur in higher frequencies in the assemblage (see Chapter 6). Overall, among the millet crops, Setaria spp. and Eleucine coracana occur in higher frequencies. The weeds include the categories SFH (Small Free heavy), SFL (Small Free Light) and SHH (Small Headed Heavy) of which the SFH predominate (69%). The Oriyo Timbo archaeobotanical assemblage consists exclusively of plant seeds, and has no rachii or other plant parts.

Local Cultivation versus Trade/Exchange

To address whether millet crops were being cultivated by the Oriyo Timbo inhabitants, the nature of the archaeobotanical assemblage, as being more indicative of lower or higher processing stages has to be determined (see glossary if clarification of

these terms is needed). The presence of rachii would have been an indicator of lower levels of crop processing, and therefore of cultivation at the site. However, as demonstrated in chapter 5, specific categories of weeds can be used as indicators of different stages of crop processing, and the categories present in the Oriyo Timbo weed assemblage (SFH, SFL and SHH) shed light on what the archaeobotanical assemblage at the site is most indicative of, earlier processing stages or later processing stages. This information is used to determine whether the crops were cultivated at the site or brought in through exchange from elsewhere. In the ethnographic record, it was observed that crop products are traded and transported over relatively long distances most often as the products of the higher processing stages.

All three weed categories in the Oriyo Timbo assemblage are indicative of higher processing stages. Given the extant weed categories, (which are indicative of the higher processing stages) the lack of any components representative of the lower processing stages (such as panicles, rachilla and large weeds), and the context of the recovery (in domestic areas), the Oriyo Timbo assemblage is interpreted as most indicative of higher processing stages such as winnowing II by shaking, most probably winnowing II product spillage or byproduct cleanings. Prior stages, sieving and winnowing I are also possible but since there are no large components the processing had to be of a finer nature.

Since the entire assemblage shows no indication of any lower processing stages, it is highly probable that these processes were not occurring at or near the site. At this point it is important to reiterate the close proximity of the seasonal stream (which would have been used in the cultivation of the crops) to the site. If crops were grown nearby, then the lower processing stages most probably would have taken place on site itself rather than away from the site in distant fields. This situation increases the probability that some components of these lower processing stages would have entered

the archaeological record given the close proximity of the stream/cultivation area to the domestic area. Therefore, it is asserted that these crop were not grown nearby but that the crop grains were brought into the site from elsewhere. Since the water source (the seasonal stream) is located in the immediate vicinity of the site, it is unlikely that they would have conducted the lower processing stages anywhere other than within the site.

Another line of evidence that strengthens this argument of trading or exchange of the crops is the lack of contextual association between the crop seeds and the non-crop/weed seeds. For example, the distribution of millets and legumes reveal that occupation II, specifically stratum 5A, has the highest frequency of crop seeds while non-crop/weeds occur in particularly low frequencies (see Chapter 6, Figure 6-3). The non-crop seeds and the crop seeds do not demonstrate any correlation of occurrence; that is, there is no pattern of associated occurrence of these two groups in the samples. This lack of co-occurrence is a strong indication that these two groups of plants were not deposited together. Specifically, a significantly higher percentage of non-crop (or weed) seeds occur in feature contexts related to food preparation, while crop plants (millets and legumes) occur in significantly higher percentages in non-feature contexts (Table 6-4).

Additionally, the higher frequencies of non-crop plants in food preparation related contexts is indicative of their use as fuel. For example, in trench S8 samples from contexts of ashy pit features (which are most probably cleanings from the food preparation areas and living floors) and scrapings above burnt hearth surfaces contain a high percentage of Mollugo sp. weed seeds.

Mollugo sp. seeds constitute the majority of the weed assemblage at Oriyo Timbo. One explanation for the presence of these seeds is that the Mollugo sp. seeds were contaminants in the food grains and were selected out and ultimately found their

way into the discard/dumping contexts that are found archaeologically. However, there is no correlation between these seeds and the millet crop seeds. For example, occupation II stratum 5A which has the highest frequencies of millet and legume seeds has a very low frequency of Mollugo sp. seeds. If the Mollugo sp. seeds were indeed contaminants/intrusives in the millet crop products, then one would predict a greater association in contexts and samples where the millet crop seeds were recovered. Therefore, a more probable explanation for the presence of Mollugo sp. seeds in these contexts is their use as fuel (intentional or unintentional), both as dried vegetative matter and as part of dung. Their inclusion into dung could be either through ingestion by the animal or as packing material.

It is important to reiterate that there is no specific relationship between the crop seeds and non-crop seeds, in that there is no association of occurrence of these two groups of seeds in any specific samples, that is there are no samples in which there is any indication of millet crops and weeds being associated together strongly. This evidence is very significant since it indicates that the sub-assemblages of crops and non-crops (or weeds) are not correlated to each other, and thus is another indication that they were not used or deposited together at the same time on the site as an assemblage. Therefore, the weeds did not enter the archaeological record of Oriyo Timbo as intrusives in the crop products and thus cannot be used as indicators of crop processing stages. This only reaffirms the interpretation that the crop grains were brought into Oriyo Timbo as a cleaned product, and there is no evidence of any significant cleaning of the crop products. This occurs only when the crop is at the highest of the processing stages, and is most indicative of having been brought to the locale in that state.

I proposed in chapter 6 that most of the crop seeds recovered at Oriyo Timbo are not from dung being used as fuel, but rather their inclusion in the archaeological record is evidence of their use as food. This interpretation is supported through two

avenues of evidence. First, crop seeds show significantly lower frequencies in the features related to food preparation at Oriyo Timbo, while non-crop/weed seeds occur in significantly higher frequencies in these contexts. Therefore, there is an apparent association of the non-crop/weed seeds with the food preparation related features, while the crop seeds show a significant association with non-feature contexts. If indeed the crop seeds recovered from the sediments of Oriyo Timbo were dung related, then it is predicted that they would show a higher frequency in the food preparation related features where dung would have been used as fuel. Plastering of floors was not observed at the site, and this eliminates the inclusion of the seeds from dung plastered floors. The second line of evidence that supports the interpretation of the crop seeds not being dung related, is that if the crop grains were acquired by the Oriyo Timbo inhabitants through trade or exchange or grown elsewhere (outside the locales) and brought into the site as highly processed assemblages for human food, then it is highly unlikely that they would have used grain to feed animals. This would have been an extremely costly strategy when wild forage would have been available in the surrounding vicinities of the site.

Even though the archaeological patterns fit in well to the expectations of ethnographic models, it is very important that other factors (related and unrelated to crop processing), which could produce the patterns observed in the Oriyo Timbo archaeobotanical data, be addressed. There are two other situations which could produce patterns indicative of higher processing stages and these are addressed below.

One factor which could skew the interpretation that the Oriyo Timbo inhabitants only conducted higher processing stages is that the lower processing stages occurred outside the site and therefore cannot be identified. Although this is conceivable there are several reasons for considering that the probability is very low. First, even if the

initial processing stages (threshings) occurred outside the site, one would still expect that some of the subsequent stages (such as sieving and winnowing I) occurred within the site. None was discerned. Second, even if the occupants were cultivating it was undoubtedly done in close proximity since the stream bed is within meters of the site. Given this situation it is highly unlikely that the lower processing stages would occur away from the site.

It is also important to note that since the occupants of Oriyo Timbo are considered seasonal migratory pastoralists, it is unlikely that crops were cultivated on a large scale. If indeed they did cultivate crops, it is much more probable to have been on a small scale geared just for consumption since the focus of their subsistence system was on animal husbandry. Given the small scale cultivation, it would rarely entail the investment of time in doing crop processing in the fields (given close proximity of the site to the cultivation areas, and also the amount to be processed). For example, why invest labor into the preparation of a threshing floor in the fields when threshing could be done at the home base where floors do not need to be prepared. Thus, it is unlikely that the lower processing would not be identified and discovered archaeologically, thereby the probability of cultivation occurring near the site is considered to be very low.

Additionally, Rissman's (1985) seasonality data places the seasonal occupation of Oriyo Timbo during the months of March through July. If one accepts such seasonality data and considers it reliable, then it can be used to argue that millet cultivation by the site occupants is unlikely. Traditionally, millets are summer crops and are cultivated after the monsoon rains in the months of August through November. Only the modern genetically engineered hybrid millets can be cultivated in the winter months, under irrigation. It is highly unlikely that the Late Harappan millets were genetically viable for winter cultivation. Therefore, using this seasonality evidence it

can be asserted that cultivation of millets by Oriyo Timbo habitants during the months of March through July is improbable.

Another factor which could skew the interpretation that the Oriyo Timbo archaeobotanical assemblage is representative of higher processing stages (winnowing II product spillage or byproduct cleanings most probably) is that the absence of rachii and rachillas due to them not surviving into the archaeological record and inhibiting the identification of the lower processing stages. Experimental studies on the charring and endurance of rachii, rachillas and spikelets of the various millets (chapter 5) showed that these components endure burning and there is a high possibility of their survival into the archaeological record. Even if one assumes they did not survive, in the specific case of Oriyo Timbo the weed categories can still be used as isolating variables for lower or higher crop processing stages. It is very highly unlikely that a situation similar to 'Opportunistic' Cultivation (where the crop fields are sterile for weeds) would be occurring at Oriyo Timbo since the area lacks the appropriate geological context that requires a heavy clay flood plain.

Thus, given all these lines of evidence, the crop seed archaeobotanical assemblage of Oriyo Timbo is most indicative of a situation when the crops are being brought into the site from outside, as essentially cleaned (of weeds, rachii, rachillas etc.) products. There are no other factors (related and unrelated to crop processing) that could produce the patterns observed in the Oriyo Timbo archaeobotanical data. The crop grains could have been brought into the site by the occupants, from their settlements in other parts of the general area, or obtained through exchange with local farmers.

Economic Use of Plants : Food or Fodder

In order to interpret whether the Oriyo Timbo archaeobotanical assemblage shows characteristics of being a food-like assemblage, a fodder-like assemblage or a combination of both, a series of issues must be addressed. First, the characteristics of food-like and fodder-like asemblages need to be elucidated and summarized based on ethnographic research. Then the Oriyo Timbo material can be rigorously correlated to the two different situations or to a combination of the two assemblages. To achieve this, the entire archaeobotanical assemblage and the sub-assemblages of crop seeds and the non-crop/weed seeds (particularly since they do not show any association and correlation of occurrence) from the site needs to be considered.

The first step entails gaining a lucid perspective of what is human food versus animal fodder. Food and fodder assemblages are quantitatively and qualitatively distinct (as discussed in chapter 5). A food-like assemblage is one that is closely related to being used as human food (immediately or through later processing). In the models presented previously (Figures 6-9, 6-11), all products of the crop processing stages, especially in the higher processing stages, are found with food-like assemblages. Typically they include dominant proportions of crop grains (husked or dehusked), along with weeds categories whose morphological characteristics are similar to the crop seeds (SFH and SFL). They also include significantly smaller sized components than the lower processing stages. The higher stage assemblages are rarely fed to animals as fodder since they are the products that have already been extensively processed for ultimate use as human food. In the rare ethnographic cases in India, when animals are fed these products, it is for very specific reasons and of very short duration. For example, feeding of such products during specific festivals, and to pregnant cows particularly if they are malnourished and need improved diets.

A fodder-like assemblage is not always derived from crop processing stages,

since it includes the byproducts of the different stages and also wild forage collected intentionally for animal feed. Archaeobotanically only the former situation can be determined with certainty, since the latter assemblage can be often confused with fuel. However, bone chemistry can be used to gain further insight into the diet of the animals. A fodder-like assemblage related to crop processing may include any or all byproducts from the different processing stages. In the models presented in chapter 5 (Figure 5-9, 5-11), the ethnographic crop byproducts from all stages are fodder-like assemblages. They typically include significantly lower frequencies of crop grains, and are dominated by the non-grain components of the crop (such as straw, panicles, chaff, rachii, rachillas, undesirable spikelets and weeds).

Based on the patterns observed in the Oriyo Timbo archaeobotanical assemblage, the overall assemblage is interpreted as consisting of food-like assemblages, and fodder-like assemblages that are not derived from crop processing products or byproducts. Specifically, spatial contexts of the samples with millet and legume crop seeds are distinctly correlated with spillage and cleaning episodes. As discussed earlier, they are comprised of only seeds with no rachii, rachillas and spikelets. In addition, there is the distinct absence of strong correlation between the crop seeds and weed seeds, indicating they were not deposited together. The millet assemblage is thus interpreted as being derived from a relatively high processing stage, most likely a crop product, and thus very much a food-like assemblage.

The non-crop/weed assemblage however, is more similar to either a non-crop processing fodder-like assemblage, or fuel for food preparation assemblage. It is not related to byproducts or cleanings from the food-like assemblages. This assertion is supported by the lack of strong association of weed seeds to crop grains and non-grain components such as rachii, rachillas and spikelets. Additionally, the non-crop/weed

seeds were found to be significantly associated with the food preparation features. This could be attributed to several processes, including crop product cleanings swept into hearths, their incorporation into dung which was then used as fuel, and use as fuel. As established earlier, the non-crop/weed seeds are not considered a crop processing byproduct assemblage. To reiterate, there is loss of crop grain (of the smaller immature crop grain) during any crop product cleaning (as discussed in detail in chapter 5), and such grains would be associated with contexts where byproduct cleanings of non-crop/weed seeds occur. The absence of this association affirms that such byproduct cleaning did not occur at the site.

In summary, given the lack of evidence for lower crop processing stages, it is argued that cultivation of millet crops was absent at Oriyo Timbo. It is, however, possible that since the Oriyo Timbo inhabitants were seasonal occupants at the site, they could have cultivated the millets elsewhere in another region, and brought them to the site at the time of occupation as highly processed crop products at the higher processing stage levels. Nonetheless, by demonstrating the absence of millet cultivation at Oriyo Timbo one of the major objectives of this dissertation has been achieved.

Model for Plant Usage and Subsistence at Oriyo Timbo

Based on this new research and previous investigations, the subsistence system of Oriyo Timbo is interpreted as primarily geared towards animal husbandry, and cultivation of millets was not practiced. However, millet crop usage for human food was an important aspect of the subsistence economy, even though these grains were brought into the site from elsewhere. The site was occupied in the months of March through July based on Rissman's (1985) study of annular rings on cattle teeth. This time frame spans the seasons of late winter, entire summer and early monsoons. The location of the site optimized the proximity to a water supply (which is crucial when

herding a large number of animals), close distance to contemporaneous Late Harappan farming villages and the readily available wild forage in the area.

Plant utilization at Oriyo Timbo was extensive and the plant usage model (Figure 7-1) elucidates this. The Oriyo Timbo plant usage model presents the plants that were intentionally brought into the site, and they are comprised of crop plants, wild forage, collected wild food plants, fuel and building materials. The human subsistence system most likely included the use of millet grain and legumes, supplemented by the collection of wild plants such as Chenopodium sp., Amaranthus sp. and Datyloctenium sp.. Animal meat consumption (both the domestic and wild) contributed significantly to the diet of the inhabitants (Rissman and Chitalwala 1990). Given the importance of animal husbandry at Oriyo Timbo, wild forage collection for animal feed was probably an important subsistence related activity. Some wild forage collected might have included Mollugo sp., Trianthema sp., Phyllanthus sp., Cyperus sp., Digera sp., Digiteria sp. and Urochloa sp. as represented in the archaeobotanical assemblage of the site. Carex sp., Solanum sp. are not edible and were probably used as fuel.

Since the months of the site occupation do not coincide with millet harvest seasons (which are most often during the months of October and November), it is unlikely that the occupants could have obtained millet crop processing byproducts from neighboring villagers for use as fodder, unless the byproduct was stored by the farmers for later use. In any case, the consumption of millet crop processing byproducts as fodder was most probably immediate and hence cannot be identified through archaeobotanical research.

The plant usage model (Figure 7-1) shows millets (being brought into the site obtained through trade and exchange) at winnowing I or II stage. The usage and disposal of the plants (both crops and wild plants) is complex but several processes have

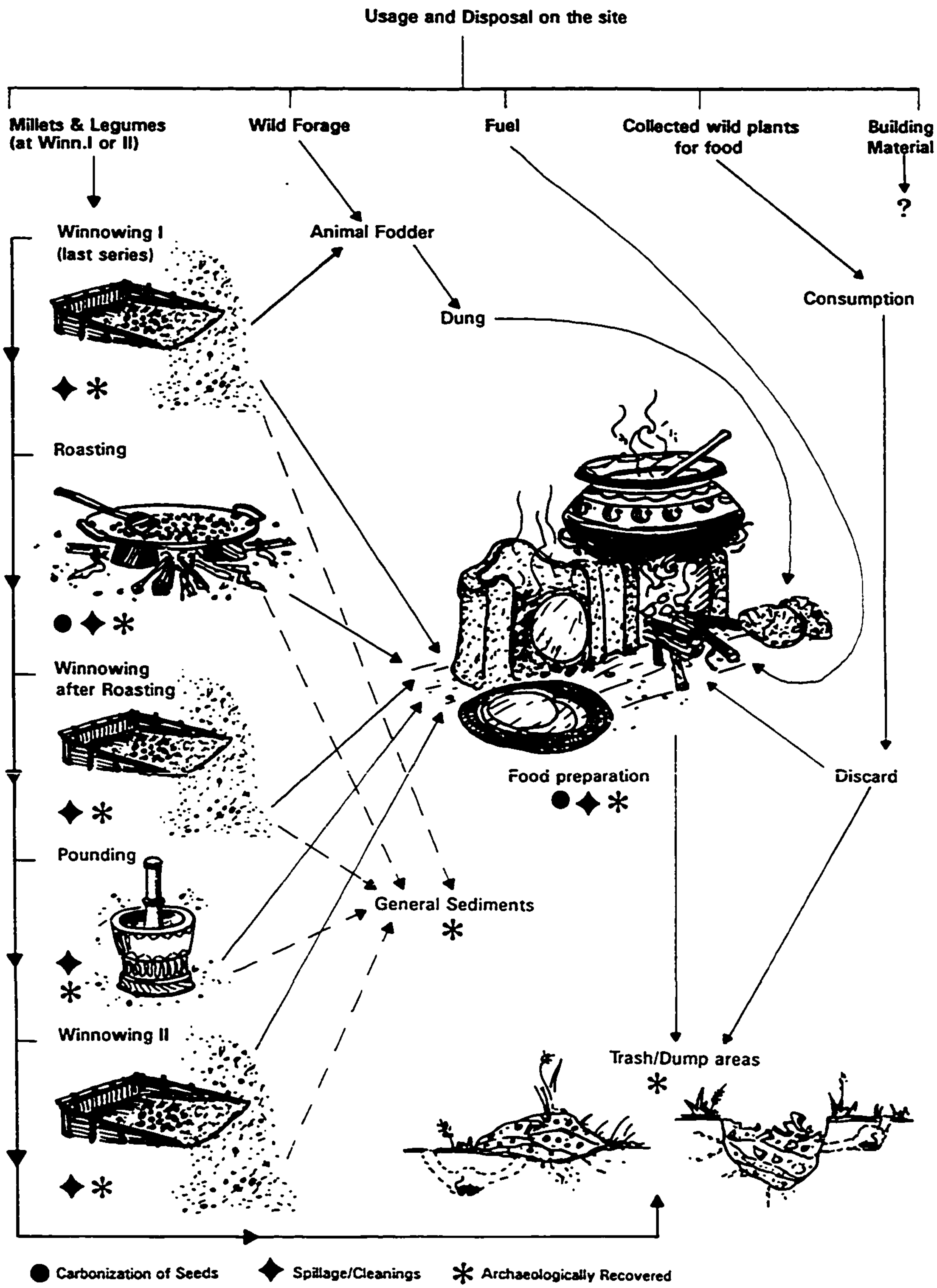


Figure 7-1. Oriyo Timbo Plant Usage Model

been elucidated, including roasting, winnowing after roasting and winnowing II. The disposal of the crop seeds as primary and secondary refuse has been identified and includes hearth contents, trash/dump pits. Although the model presents several processes, all the processes need not have occurred in one locale or throughout the duration of site occupation. The presence of these processes during the Late Harappan occupation of Oriyo Timbo, however, reiterates that millets were the primary food crops, and the subsistence diet was supplemented by wild plant resources.

Further insight into the character of pastoralism and animal husbandry at Oriyo Timbo can be gained by drawing on ethnographic observations of modern pastoralists in Gujarat (specifically their interaction with farmers and fodder acquisition). Traditional agriculture is an important subsistence economy in this region of India, but it is usually complemented by two different forms of pastoralism: pastoral nomadism and semi-nomadic pastoralists. The definitions of these two forms of pastoralism have been developed by Khazanov (1983). His classification is an economically oriented system focussing on the degrees of pastoral dependence on agriculture. Pastoral nomadism is characterized by the absence of agriculture altogether, with grains and other domestic crops obtained from other groups. In contrast, semi-nomadic pastoralists are characterized by pastoralism as the major economic activity; however, agriculture occurs as a secondary and supplementary activity. In Gujarat both these types of pastoral groups are observed, with two main types of pastoralists within each group: cattle and goat herders, and camel herders. Seasonality is an inherent ecological factor in the region, and the seasonal flow of the rivers and other ecological constraints in the area, such as the seasonally availability of wild grasses, contribute to making pastoralism an important subsistence economy.

The pastoral nomads rarely practice agriculture, even on a seasonally limited basis, and survive through animal husbandry. Pastoral communities making their living

on animal breeding is a distinctive feature of rural Gujarat. Being mostly a landless group, their stock is dependent on community grasslands for survival. Therefore, migrations are determined primarily by pasture availability. The main annual movements are from the north and northwest towards the more fertile and forested area to the east and southeast in the post monsoon months (Patel 1977). The seasonality of this movement has a direct effect on fodder acquisition and its utilization by stock. Often the pastoralists migrate with the entire family and stay in specifically chosen areas for nearly six months. During their migration, the duration of the temporary camps is usually dependent on how long local inhabitants allow them to stay at one place. En route they often rent plots of fields from farmers, camping directly on these field plots and paying their rent with animal manure.

In some cases, semi-nomadic and semi-sedentary pastoralism is also observed in Gujarat, with permanent pastoral settlements situated within villages, and these pastoralists occationally own land to cultivate for subsistence. These semi-nomadic and semi-sedentary pastoralists practice agriculture, both for human consumption and animal fodder, and the extent of its importance varies depending on the group. In both cases, the pastoralists still participate in seasonal migrations. Very often part of the family (the elderly and often also women) remains in the village with some of the herd, usually the goats, while the rest of the family takes the cattle southward for pasture grazing in the summer months (March through June).

Given the juxtaposition of villages and pastoralist communities in the area during the Late Harappan phase in Gujarat, it is conceivable that the occupants of Oriyo Timbo may have participated in a related interaction system. The site of Oriyo Timbo could have been a part of a seasonal round for a pastoral-nomadic community who engaged in trade and exchange with the local agriculturalist for food grains. Or, Oriyo

Timbo could have been the seasonal camp of semi-nomadic or semi-sedentary pastoralists engaged in a mixed and integrated economy of farming and pastoralism, and thus bringing with them highly processed crop products on their seasonal migrations to the site. The existing regional data for the Gujarat Mature and Late Harappan traditions, however, are not detailed enough to test such hypotheses at this time. Nonetheless, it is important to be cognizant of such economies and settlement patterns while suggesting alternative explanatory models for the occupation of Oriyo Timbo.

Fodder acquisition and utilization among the pastoralists in Gujarat is very specific and highly organized. There are distinct differences in fodder usage for cattle, water buffalo and goats. In general, cattle and water buffalo are fed both dry and green fodder, while goats and sheep are fed only green fodder. Pennisetum typhoides, and Sorghum bicolor byproducts obtained dry from farmers usually in exchange for animals products (such as milk, butter, fur or manure) are fed to the cattle, but not to sheep and goat. Additionally, cattle are fed Pennisetum typhoides chaff and straw, while water buffalo are given only Sorghum bicolor straw and chaff. The reason for this pattern is not entirely clear. There is a significant difference in the crude fiber and crude protein between the straws and chaff of the two millets, and this may be the determining factor in the effectiveness of different fodders for cattle versus buffalo.

Goats and sheep are not fed dry fodder since it negatively affects milk production, and hence green fresh fodder is always preferred. This is a surprising and important observation, since goats are capable of existing on a nutritively poorer diet, but the pastoralists of Gujarat never feed their goats dry fodder. Often the green parts and the seeds of field weeds such as Trianthema portulacastrum, which often grow in millet crop fields, are selectively collected and fed to goat (and cattle). Some common wild fodders, such as Eremopogon foveolatus and Apluda aristata, are collected and fed to cattle and goats.

Fodder utilization by pastoralists is very seasonal. For example, selective collection of the wild fodder Cressa cretica (popularly called Bokhna) is common in parts of North Gujarat. Cressa cretica is readily available in November/December since it needs a lot of dew for its growth. It is used only as a green fodder and it is the first preference when it available since it enhances milk production. As it cannot be stored as dry fodder, it is used profusely while available, after which other fodders are used. In the months when this wild fodder is not available, other wild fodders and millet byproducts such as Pennisetum typhoides straw and chaff are used. Brassica sp. and Amaranthus sp. are two other plants (cultivated and wild varieties) used and selected specifically by pastoralists for animal fodder during other portions of the year. Such seasonality in fodder intake is common in northern Gujarat. Even in other areas of Gujarat, the pastoralists follow similar patterns of fodder utilization, feeding the selectively collected wild fodder during the rainy season of July through August. Millet byproducts such as Pennisetum typhoides straw and chaff are used in the summer months of March through June. Moreover, they often have to buy Pennisetum typhoides straw when other fodder is not available.

My ethnographic research has noted interaction between pastoralists and settled farmers in different parts of Gujarat, and this interaction involves considerable exchange of food and fodder between these two complementary groups. Such a pattern and exchange system has important implications for Oriyo Timbo, and it is possible that such interaction might have occurred between the inhabitants of Oriyo Timbo and settled farming neighbors. In ethnographic situations, pastoralists often exchange animals and animal products such as milk, butter and processed butter for crop grains (for human consumption) and crop byproducts (for animal fodder). Crop byproducts are fed to the cattle (but not to the goats) when wild forage is scarce. In general, there is

specific selection of wild forage with attention being focussed on the inherent 'milk-producing' qualities of the wild plants. This is important because milk production defines the success of a pastoralist economy. For example, green fresh forage is preferred over dry plants, since it enhances lactation, while dry forage has a tendency of limiting milk production in some animals.

Based on the previous discussion, four main observations regarding Gujarat are relevant to interpreting the occupation of Oriyo Timbo and in general for understanding the Late Harappan in the area.

1. There is an interdependence (complementarity) between the agriculturalists and the pastoralists.

2. There is considerable seasonality in fodder acquisition and utilization by both pastoralists and farmers. The emphasis on fodder is dependent on how important the animals are for the economy (apart from being load animals).

3. There is selective fodder acquisition by the pastoralists, mainly dependent on the effect the fodder has on milk production.

4. In some cases, the pastoralists are involved both in animal husbandry and small scale cultivation. The emphasis varies depending on the year and specific needs.

The interplay of farming and herding within an uncertain semi-arid environment is characteristic of Gujarat. Rissman (1985:366) proposed that a lack of security in regular yields prehistorically would have led to the build-up of cattle herds to ensure a successful subsistence economy. Moreover, farming practices might have been temporarily abandoned and a period of specialized pastoralism developed in the face of continued agricultural uncertainty. Conversely, increasing confidence in cultivation would allow a household to dispose of animals to a level at which some degree of village life would again be viable. Observations of contemporary pastoralists and agriculturalists of Gujarat, however, do not support this scenario. Instead, a whole

range of possible adaptations, from pastoral nomads with no cultivation to semi-nomadic pastoralists who practice some cultivation to settled farmers is documented. Therefore, if cultivation failed prehistorically (as suggested by Rissman) the succeeding economy need not necessarily have been pastoralism to the total abandonment of cultivation. Instead, it is more plausible that a combination of the two economies took place. Additionally, there are no archaeological data (climatic or archaeobotanical) that indicate major failure in the agricultural systems of the Gujarat Late Harappan.

Thus, the ethnographic evidence demonstrates that pastoralism and agriculture can coexist and need not be successive and alternate economic strategies. I propose two alternate possibilities for Gujarat Late Harappan settlements: pastoral nomads and agriculturalists, and semi-nomadic pastoralists conducting small scale agriculture or semi-sedentary pastoralists supplementing their dominant subsistence economy of agriculture with pastoral activities. The first case occurs when there is a constant interplay between pastoralists and agriculturalists in terms of balancing resources. The second case is when there is a complex interlacing of the two economies, pastoralism and agriculture in the same group. In the context of Oriyo Timbo, I suggest that it is probable that any of these interactions and integration of economies were present.

At Oriyo Timbo, animal husbandry was the key subsistence practice. The occupants were thus obliged to concentrate their subsistence related activities on fodder acquisition, either wild forage collection, and also they may have exchanged with the neighboring farmers for crop grains (for human food) and crop byproducts (for animal fodder). Rissman (1985, 1987) and Ryan (1990) both suggest that the age profiles at death for cattle show predominantly young adults, juveniles with young calves in small numbers. They suggest that this is a possible reflection that this was a fallow herd with few lactating females. The slaughter of young juveniles and young calves implies that

animal meat was an important component of the diet and possibly used in exchange with farmers.

In summary, when the archaeobotanical and archaeofaunal studies are considered together, it is most probable that Oriyo Timbo inhabitants were part of a larger, more complex regional settlement and subsistence system. The inhabitants of Oriyo Timbo were not self sufficient. Instead a complementary subsistence system existed between the pastoral nomadic, semi-nomadic or semi-sedentary pastoralist inhabitants of Oriyo Timbo and the neighboring farming villages, based on exchange of human food in both directions and the acquisition of fodder by the pastoralists.

Babar Kot

To address the economic importance of millet cultivation at the site of Babar Kot, it is imperative to first determine whether the millet crops were being cultivated by the site occupants. Subsequently, determination of the role of these crops (as food for humans, fodder for animals or both) in the subsistence economy, and the degree of reliance on them is necessary to elucidate their economic importance to the occupants of Babar Kot. Then a working model for the plant usage and subsistence at the site will be presented that summarizes the findings of this research project.

Local Cultivation versus Trade/Exchange

The first step in examining the issue of whether crops are brought in from elsewhere or cultivated by the inhabitants is to correlate the archaeobotanical assemblage of Babar Kot to the lower or higher processing stages. First, the Babar Kot archaeobotanical assemblage is correlated to a situation of cultivation by the inhabitants versus crops being brought in from elsewhere, then the presence or absence of other factors which could produce similar patterns in the archaeological record need to be

addressed.

The archaeobotanical assemblage from the site consists of millet seeds, legumes seeds, oilseeds, millet spikelets with rachillas and rachis fragments, and the four weed seed categories. Overall, crop seeds dominate the assemblage. The presence of spikelets with rachillas and rachis fragments, however, is crucial in discerning the nature of the assemblage. These two components are not representative of most of the higher processing stages such as roasting, pounding, winnowing II or grinding. As shown in the study of crop processing stage products and byproducts of Panicum miliare and Setaria tomentosa in chapter 5, rachis fragments are indicative of lower processing stages. Rachis fragments are processed out predominantly through sieving. Spikelets with rachillas are also indicative of lower processing stages, although they occasionally occur in the final winnowing I process of the higher processing stages. They are predominantly processed out through the sieving and winnowing I process. Presence of these two components is a strong indication of two situations; that these two processes were conducted at the site, or that these processes had yet to be conducted. In order to determine which of these two situations is most probable, context and association must be examined, for example, spikelets and rachii occur in significantly higher frequencies in feature contexts and in association with crop and weed seeds.

In addition to the rachilla and the rachii, weed categories are also used to identify the crop processing stages represented. The Babar Kot weed assemblage includes four categories: those of SFL (Small Free Light), SFH (Small Free Heavy), SHH (Small Headed Heavy) and BFH (Big Free Heavy). The ethnographic modeling presented in chapter 5 has demonstrated that specific categories of weeds can be used as indicators of different stages of crop processing, and the categories present in the Babar

Kot weed assemblage (SFL, SFH, SHH and BFH) can be used to shed light on whether the archaeobotanical assemblage is most indicative of an earlier or later processing stage. In general at Babar Kot, weeds occur in significantly higher frequencies in feature contexts. Thus, their presence is correlated to specific human behavior and activities, most probably linked to crop processing and food preparation. The SFL (Small Free Light) category of weeds dominate the assemblage accounting for 69%, with SFH (Small Free Heavy) weeds well represented (30%). The remaining two categories (SHH and BFH) together occur in very low percentages (0.6%). They cannot be ignored, however, without comment since they occur exclusively in feature contexts at Babar Kot and thus are a result of human activity. The BFH (Big Free Heavy) category is represented by wild Zizyphus sp. which are not necessarily weeds since their are commonly collected for human consumption. Its presence in the archaeobotanical assemblage at Babar Kot is attributed either to intentional collection and use as human food unconnected to crop processing, or possibly weeds being processed out from crop products. The SHH (Small Headed Heavy) weed category is represented exclusively by Phyllanthus sp. which is a common weed in millet fields and is also fed as green cattle fodder.

The four weed categories (including the BFH category) that define the Babar Kot weed assemblage are indicative of both lower and higher processing stages. It is particularly significant that the SFL weed category (represented by Cyperus sp., Eragastis sp., Phalaris sp., Polygonum sp., and Urochloa sp.) occurs in the highest frequency. These weeds are morphologically distinct from the crop seeds of Panicum miliare and Setaria italica which are essentially small, free and heavy (SFH) seeds. As discussed in chapter 5 weeds which have similar characteristics to the crop grains are processed out in the higher processing stages while the weeds which are most distinct from the crop grains are processed out in the lower processing stages. Applying this

observation to the Babar Kot weed assemblage, the higher ratios of the SFL weeds is a positive indicator of the lower processing stages.

Complementing this on-site processing is the strong presence of the SFH (and a lesser presence of SHH) category which is an indicator of higher processing stages. However to distinguish the two levels of processing more securely, the weed category data has to be used in conjunction with the data on rachis fragments and spikelets with rachillas. Given the weed categories, the presence of rachis fragments and spikelets with rachillas (the key components of lower processing stages) and, the contexts and features of archaeobotanical recovery, the Babar Kot assemblage is interpreted as indicative of both lower and higher processing stages. These include the stages of sieving, winnowing I, winnowing II and possibly pounding (due to the presence of cracked millet grains in specific contexts). Overall, the assemblage demonstrates that a considerable amount of crop cleaning took place at the site (as presented in chapter 6) and this sheds light on the nature of distinct and important activities related to food preparation and consumption.

Given the identification of lower and higher crop processing stages in the archaeobotanical assemblage of the site of Babar Kot, it is now appropriate to comment on the implications of this conclusion. The presence of lower crop processing stages is indicative of a certain degree of proximity to the first stage of crop processing, harvesting and threshing, which occur only if there is cultivation at the same locale. If the crops were obtained through trade or exchange, the lower processing stages would not be observed. This leads to the ultimate deduction that the crop grains are being cultivated in the general environs of the site, most probably by the site occupants themselves. The presence of the higher processing stages indicates that the cultivated crops were undoubtedly used as human food. The possible use of the crops as animal

fodder, however, needs to be explored further.

Earlier in the chapter, the presence of crop seeds at Oriyo Timbo was interpreted as evidence of their use as human food and not the result of their presence in dung that was used as fuel. Similarly, the means by which the Babar Kot crop seeds entered the archaeological context needs to be established, especially since there is a strong association between high frequencies of crop seeds and feature contexts.

Two avenues of evidence support the interpretation that the Babar Kot crop seeds are for use as human food and not present due to incorporation into dung which was subsequently used as fuel. First, only one of the features at Babar Kot is a context where dung would be used as fuel, a hearth/cooking feature. All other features are dumps or trash pits related to domestic activities and could be the result of cleaning hearths and cooking features. The crop seeds recovered from these trash dump contexts are very unlikely to be dung related, since the burning of the dung as fuel would completely destroy them. Instead, they are interpreted as crop product cleanings associated with food preparation. Therefore, given the nature of the feature contexts the crop seeds are interpreted as not related to incorporation into dung, instead their inclusion is indicative of their use as human food.

A second line of evidence supporting this interpretation is also present. The strong evidence of lower and higher crop processing activities at the site further supports this assertion since these activities are not performed on crops cultivated only for animal fodder. The majority of situations where a crop is cultivated as animal fodder it is harvested before seeding and then fed as green fodder. More often crops are cultivated to use the grain as human food and the byproducts are then fed to animals as fodder. Therefore, given both of these lines of evidence it can be asserted with certainty that the crop seeds were not incorporated into the Babar Kot archaeobotanical assemblage through the use of dung as fuel.

In addition to the identification of key elements of different levels of crop processing stages, several spatial and contextual patterns distinguished from the Babar Kot data strengthen the argument that these crop processing activities are present. As mentioned earlier, there is a strong association between weeds and millet seeds. In general, both plant groups (crops and weeds) occur in significantly higher frequencies in feature contexts. This directly connects these remains to human activities related to crop processing and food preparation. There is a distinct spatial pattern in the distribution of Setaria spikelets with rachillas. They occur exclusively in the feature contexts of the slope units at Babar Kot. In addition, Setaria rachii occur in significantly higher frequencies in features within the slope (and to some extent on the mound as well). This pattern reveals that lower processing activities related to the cleaning of Setaria crop products were occurring predominantly in the slope area. Thus, it appears that this area of the site was where these processing activities were concentrated. Linum sp. seeds also have the same spatial and contextual association. Linum sp. seeds, all showing rupture signs on the narrow ends, occur exclusively in the slope units and in significantly higher frequencies in feature contexts. Although speculative, it is plausible that this pattern is indicative of a processing activity either for extracting oil or for cleaning the seeds for human consumption.

Another spatial distinction related to crop processing activities entails the distribution of the various weed categories. The mound weed assemblage is characterized by the dominance of two categories; SFL (49%) and SFH (50%). The slope weed assemblage reveals a dominance of SFL (66%) weeds with the SFH (32%) weeds occurring in lower but moderate frequencies. In addition, the slope weed assemblage also includes a significantly higher frequency of SHH (Small Headed Heavy) and BFH (Big Free Heavy) weed categories (1.3% versus 0.4%). Ethnographic

models indicate that the crop product and byproduct weed asemblages which are dominated by both SFL and SFH weed categories (as seen in the mound weed assemblage) are primarily those related to lower processing stages such as sieving and winnowing I (see model tabulations of chapter 5). However, in contrast the later series of winnowing I are dominated by the SFL weed category (as seen in the slope weed assemblage).

The combination of weed and crop spatial distribution reveals a distinct pattern related to crop usage and processing at Babar Kot. The millet crop seed distribution in the mound area of the site includes Setaria italica (78%), Panicum miliare (20%) and Eleucine coracana (1%), while the slope area has Setaria italica (94%) and Panicum miliare (6%), but no Eleucine coracana. The significantly higher percentage of Setaria sp. in the slope implies greater usage (and processing) in this area. In addition, the exclusive presence of Setaria spikelets with rachillas, the significantly higher frequencies of Setaria rachii, and associated weed categories in the slope indicate there is a higher occurrence of both lower and higher processing activities related to Setaria italica in this part of the site.

On the mound, the presence of SFL and SFH weed categories indicative of lower processing stages associated with Panicum miliare indicates that lower processing stages of Panicum miliare took place on site. This implies local cultivation by the inhabitants. This argument is strengthened by the association of Panicum miliare seeds and both the SFL and SFH weed categories specifically with feature contexts.

Thus two important inferences are made. First, both Setaria italica and Panicum miliare were cultivated near the site and processed on site. Second, there is spatial distinction in where the processing of the two crops occurred. Setaria italica was predominantly processed on the slope while Panicum miliare was more often processed on the mound.

A series of temporal patterns are also important to consider in examining the issue of local cultivation and processing. There is a significant difference in the frequency of carbonized seeds recovered from the three occupations at the site. Occupation III has a significantly higher frequency of carbonized seeds recovered per liter of sediment (see chapter 6). This pattern could indicate either differential usage of plants through time, or temporal variations in crop processing. At Babar Kot, it is argued that the differential usage of plants through occupations is most probable. This assertion is substantiated by the following arguments. First, all the plants recovered at Babar Kot (regardless of occupational level) are Type B crops which all require similar type of processing. Both of the major crops, Setaria italica and Panicum miliare, are hulled crops in that their grains are enclosed by tough glumes and the release of the grain requires more than threshing. Therefore, similar crop processing is required for both the crops.

Second, even though Occupation I has only Panicum miliare and there are no rachii or spikelets with rachillas, the weed assemblage from this occupation is comprised of equal percentages of SFH and SFL categories. These are indicative of lower processing stages. Thus, it appears that in occupation I the site inhabitants were only (or predominantly) cultivating and processing Panicum miliare. In occupation II, however, Setaria italica was introduced and its cultivation is indicated by the presence of rachii and spikelets with rachilla (both indicative of lower processing stages). A noted decrease of Panicum miliare occurs in occupation II (refer to Table 6-7 for the data). In occupation III, there is steady and significant increase in Setaria italica seeds, rachii and spikelets with rachillas. Panicum miliare increases in frequency during occupation III but still at significantly lower frequencies than Setaria italica. The Panicum miliare seeds recovered from occupation II were recovered in significantly

higher frequencies from feature contexts indicating direct association with food preparation and consumption. So even though there is an obvious decrease in the use of this crop in occupation II, its fundamental usage as human food continues. This decreased use of Panicum miliare in occupation II is most likely related to the addition of Setaria italica and not due to variations in processing pathways.

Setaria italica occurs in significantly higher frequencies in occupation III. There is distinct increase in the usage of this crop at the site from occupation II to occupation III, as seen in the increase in frequencies of the seeds, spikelets with rachillas and rachii of this crop from various contexts. The increase in definitely reflective of an increase of usage and it does not imply different processing activities, since there are very limited ways to processing a Type B crop (see chapter 5). Thus, there is distinct variation in plant usage over the occupation span of Babar Kot.

In addition to the variation in plant usage over the temporal span of the site, there is a distinct pattern in the stratigraphic distribution of the weed categories. The weed assemblage of Occupation I is almost equally represented by SFH (47%) and SFL (53%) weeds, while occupation II and III weed assemblages have SFL category in dominating frequencies (71% and 73% respectively). As demonstrated in chapter 5, ethnographic modeling indicates that crop product and byproduct weed assemblages represented by both SFL and SFH weed categories (as seen in occupation I) are primarily indicative of lower processing stages such as sieving and winnowing I (see model tabulations of chapter 5). In contrast, the later series of winnowing I have the SFL weed category in dominating frequencies (as seen in occupation II and III). Coupling this temporal patterning in distribution with the significant presence of spikelets with rachillas and rachii in occupation II and III, confirms the presence of activities related to several lower processing stages in these latter occupations.

Of all the crops utilized by the Babar Kot occupants during the Late Harappan,

the use of Eleucine coracana is the most problematic. Only eight caroypsis of this crop plant were recovered from the site and all occur in the mound are from non-feature contexts of occupation II and III. The low frequencies of the plant reflect its lower usage and also possible usage as green fodder. Additionally, as proposed in chapter 6, it is probable that the absence of the roasting stage in the processing of Eleucine coracana might be negatively effecting the inclusion rate of the crop seeds in the archaeological sediments.

Several contextual patterns observed in the Babar Kot archaeobotanical data need more detailed evaluation and specific application of ethnographic models, since the relevant sub-assemblages are very pertinent to the discernment of crop processing and crop usage at the site. In all seven contextual assemblages at Babar Kot are addressed in more detail, four from the mound and three from the slope.

Occupation III pot contents from within a room on the mound mainly included Setaria italica seeds of which a majority were broken/cracked. Two seeds of Digitaria sp., a SFH (Small Free Heavy) weed, were also present. In chapter 6 it was established that these seeds were indeed the original pot contents and not intrusives after the disposal of the pot. The contents were then interpreted as being related to storage of Setaria italica after the dehusking/pounding stage. The dehusked state of the seeds is indicative that consumption was planned for not too distant future, and also that these particular seeds were not intended for trade or exchange. This reveals that a very high processing stage occurred at this particular locale, a habitation room at the site and unequivocally establishes that Setaria italica grains were used as human food. How exactly the grain were consumed, cooked as rice or ground into flour cannot be ascertained with the information available.

There are three feature contexts in occupation II on the mound which are

indicative of crop processing and food preparation activities. First, a semi-spherical clay feature (which was interpreted as a hearth in chapter 6) has a heterogeneous assemblage with seven different components dominated by Setaria italica seeds (60%). The other components include a Setaria sp. rachis fragment, Panicum miliare seeds (5%), seed fragments of Lens sp. and Lathyrus mungo (.8%), and SFH weeds (2.4%). Unidentifiable seeds fragments constitute an additional 30% of the assemblage. The presence of the four different crop plants implies that the assemblage is not formed by a single event but most likely is a composite of a series of events related to the individual crop plants. The usage of Setaria italica was clearly the most substantial but since there are several events represented, it is not possible to discern the activities related to processing of individual crops. However, given the very low ratios of weeds and rachii to the crop seeds it is clear that the crop products utilized at this locale were essentially cleaned products related to higher processing stages. Their deposition into this context could be a result of several processes including cleanings from later processing stages being swept into the hearth, their spillage during food preparation, and specifically in the case of Setaria italica and Panicum miliare, spillage during roasting for dehusking.

The last contextual assemblages to be examined in detail are two feature pits on the mound in occupation II. They are of importance because they are indicative of two different activities and related to two different crop plants, Setaria italica and Panicum miliare. One pit is dominated by Panicum miliare (75%) with SFH weeds in moderate ratios (25%). The other pit is dominated by Setaria italica (86%) and is more heterogeneous with SFH weeds (4%), SFL weeds (6%), Lens sp. (2%) and rachis fragments (2%). This patterned variation between the two pits is indicative of differential processing activities pertaining to the two crop plants. The first pit (dominated by Panicum miliare) is representative of the later processing series of winnowing I by shaking, since the SFH weeds with their morphology similar to crop

grains are last weeds to be cleaned out. The absence of rachis remains or spikelets with rachillas further supports this assessment. Ethnographic models indicate that often crop byproducts of the higher processing stages include crop seeds which are selected out because of their undesirable qualities (mainly size and fungal infection). Therefore, the contents of this pit are interpreted as byproducts from a relatively high crop processing stage of Panicum miliare.

The pit contents dominated by Setaria italica is interpreted as cleanings from a lower processing activity, such as the initial series of winnowing I. This assertion is primarily based on the presence of the rachis fragments which are indicative of lower processing stages. The weed assemblage has a higher representation of the SFL weeds and the ethnographic models correlate assemblages dominated by SFL weeds to be most closely related to the later series of the lower processing stage of winnowing I. Thus, given these two lines of evidence, the pit contents were most likely related to winnowing I activities, and thus indicative of lower and a slight component of higher processing. In general, the contextual assemblages from the mound are indicative of higher processing activities, and to a lesser degree of lower processing activities.

The contextual assemblages of importance on the slope of the site are all recovered from occupation III and include a trash pit, an ash refuse pit and a seed pocket (which were all discussed in chapter 6). Their relevance to crop processing stages and food preparation activities needs to be further ascertained. The trash pit shows series of distinct dumpings, with the top-most layers being more heterogeneous including seeds of Setaria italica, Panicum miliare, Lens sp., Vicia sp. and Brassica sp.. The middle layers are characterized by Setaria italica seeds along with rachis fragments, Linum sp. seeds and SFL weeds. The lower layers show a low density of carbonized seeds (.2% of total assemblage of carbonized seeds from the feature) and

comprise exclusively of Setaria italica seeds. The patterned variation in the dumping is indicative of several processes, the most important of which is that there is there is both variation and stability in plant discard (and therefore usage) this locale of the site during the use-life of the trash pit. The patterning of plant seeds recovered, with legumes and Panicum miliare exclusively present in the topmost levels of the pit and Linum sp. seeds present only in the middle levels, is a strong indicator of the variation in plant discard and usage. In contrast, Setaria italica seeds are present through all the levels of the pit and therefore were being discarded (and used) throughout the duration of the trash pit usage. This trend is further evidence for varied importance of the different crops at the site, with Setaria italica being the key crop.

Another implication of the patterned variation of dumping into the trash pit is the presence of a distinctive assemblage only in the middle levels. This assemblage is most likely related to a cleaning byproduct of Setaria italica. Setaria italica rachis fragments are present only in the middle layers, and weeds are present in significantly high frequencies in these levels. The weed assemblage consists of SFL weeds (66%), SFH weeds (32%), SHH weeds (2%), and BFH weeds (0.3%). The dominance of the SFL weeds associated with the rachis fragments in this trash pit contexts demonstrates that this assemblage of Setaria italica seeds is representative of a byproduct related to a lower processing activity such as winnowing I or possibly sieving. These interpretations of the trash pit archaeobotanical assemblage in relationship to crop processing and food preparation are significant since they shed light on two important issues; the differential usage of plants at a specific locale on the site during one occupation time span, and the disposal of plant processing byproducts. Clearly, these plant byproducts were not fed as fodder to animals.

The second key contextual assemblage on the slope is from a refuse ash pit which was interpreted in chapter 6 as being related to domestic cleanings from cooking

fires. The archaeobotanical assemblage from this context is dominated by weed seeds (60%), with millets (35%) and legumes (5%) occurring in significantly lower ratios. The weed assemblage consists of SFL and SFH weeds in varying proportions (41% and 59% respectively) and this is important for the interpretation of the pit's archaeobotanical assemblage as it relates to food preparation or crop processing activities. Since there are two millet crops and two legume crops in the pit, and there is no distinct pattern in the distribution of these various plants remains, it is not possible to correlate individual crops to specific crop processing activities or food preparation methods. Nonetheless, the weed categories are indicative of higher processing stages since the SFH weeds constitute the majority of the weeds (as discussed earlier, the SFH weeds are processed out later in the pathway since they are most similar morphologically to the crop seeds of Setaria italica and Panicum miliare). The relatively high frequencies of SFL weeds suggests a later series of winnowing I. Overall, the assemblage is indicative of later lower processing stages and higher processing activities. Considering the high percentage of the weeds, the assemblage is most probably the discard cleanings from a crop product through a form of winnowing, fine sieving or hand sorting.

The last contextual assemblage of primary significance at the site is the seed pocket recovered from occupation III on the slope. As discussed in chapter 6, the composition of the seed pocket is most indicative of a lower crop processing stage. It is, however, important to note that the seed pocket contains two millet crop seeds (Setaria italica and Panicum miliare) and most likely includes a combination of crop processing activities performed on both the crops. The presence of Setaria rachii and spikelets with rachillas clearly indicates lower processing stages related to Setaria italica processing. The weed assemblage, however, shows a dominance of SFL weeds (66%)

along with SFH weeds in strong frequencies (33%). This is indicative of a later series of the winnowing I process, a higher processing stage. If the weed assemblage directly associated with the Setaria italica seeds, then there are two alternate scenarios for interpreting this crop sub-assemblage. The rachii fragments and spikelets with rachillas imply the presence of lower processing activities. The dominance of SFL weeds, however, suggests later series of winnowing I. Therefore, the Setaria italica processing identified through the seed pocket composition includes lower and higher processing activities.

In contrast to Setaria italica, there are no Panicum miliare rachii or spikelets in the seed pocket. Negative evidence is used to argue for a different processing activity related to this crop, most likely a higher processing stage. It is, however, plausible that the some of the weeds (discussed for the Setaria italica case) are correlated with Panicum miliare processing. Therefore, one can argue for two scenarios in interpreting the Panicum miliare sub-assemblage of the seed pocket: either crop processing or food preparation. The assemblage may represent a very high processing stage such as winnowing II where only tail grains were being cleaned out and no weeds were present. Alternatively, the assemblage may represent a later series of winnowing I where there are no rachii, rachillas or spikelets, and only weeds. In either situation, the processing of Panicum miliare is more similar to a higher stage than a lower stage. Therefore, it is clear that the seed pocket reflects separate processing of the two crops.

The archaeological patterns were interpreted using ethnographic models in the preceding discussion. Even though the archaeological patterns fit well to the expectations of the ethnographic models, it is important to address other factors which could produce such patterns as well.

The main factor which could skew the interpretation of the Babar Kot archaeobotanical assemblage as being representative of lower and higher crop

processing stages (and therefore indicative of cultivation and processing by the site inhabitants), is that the crops were being bought through trade and exchange as lower processing products or uncleaned higher processing products. These two situations are unlikely but still have to be examined and eliminated to strengthen the interpretations. If indeed the crops were being brought into the site as lower processing products, grown elsewhere, one would expect to find higher frequencies and presence of big sized weeds, panicles, larger sized rachii and rachillas. The Babar Kot archaeobotanical assemblage does not contain high frequencies of any of these components. Although it is possible that the site occupants could have brought in the crops as uncleaned higher processing stages, however the probability is very low. Ethnographically there are only extremely rare situations when products from higher processing stages are unclean. Given the nature of Babar Kot, with its substantial architecture, sedentary nature and relatively high population, it is highly improbable that the occupants were obtaining crops through trade and exchange. Furthermore, the surrounding environs would have supported year round cultivation. Given this situation, it is argued that the Babar Kot occupants were undoubtedly cultivating the crops in the vicinity and this is reflected in the archaeobotanical assemblage of the site.

Economic Use of Plants: Food or Fodder

The next issue to be resolved involves the interpretation of the Babar Kot archaeobotanical assemblage as being more likened to an assemblage which is food-like, fodder-like or a combination of both. The botanical distinction between food-like and fodder-like assemblages, as they relate to crop processing stages, have already been presented for Oriyo Timbo and the same distinctions apply for this discussion. It is necessary to comment that the fodder-like assemblages are the crop processing

byproducts, but they need not necessarily be used as fodder. To ascertain whether these byproducts were used as animal fodder, the assemblages need to be from specific contexts (such as dung as fuel, dung plastering, etc). In the absence of such contexts, then the fodder-like assemblages are considered crop byproducts which potentially could have been used as fodder.

Based on the patterns observed in the Babar Kot archaeobotanical assemblage, the entire assemblage is best correlated to being closely related to various crop processing stages byproducts. Even though the assemblage is not food-like, there is definite evidence for use as human food based on the presence of crop byproducts from higher processing levels. Additionally, the presence of byproduct assemblages related to crop processing can be used to infer their use as fodder. However, additional archaeobotanical research at the site geared toward excavation and study of contexts where fodder-like assemblages would be likely recovered, such as hearths, floors and wall plasters, is required to strongly establish the presence of fodder-like assemblages. Equally important to this issue are other lines of evidence such as bone chemistry.

The millet assemblage patterning at the site shows a very distinct correlation to use as human food. Several contextual patterns have been interpreted as being related to lower processing and higher processing activities. These processing activities occur only if a crop is being used as human food. Any use of processed crop products as fodder is only secondary. In a majority of the contexts, the Babar Kot millet assemblage is indicative of the byproducts rather than products of crop processing, be it a lower processing stage or a higher processing stage. This negative mirroring of the processing is evidence for the use of millet crops as human food.

Model for Plant Usage and Subsistence at Babar Kot

The subsistence system at Babar Kot was geared toward cultivation of various

crops, wild plant collection, and to an extent animal herding. The settlement is one of permanence with relatively substantial architecture and distinct domestic activity areas. It was undoubtedly occupied all year round (based on a variety of factors including the plants cultivated), and given the considerable size of the population the subsistence system needed to accommodate long periods and relatively high demands. This was only possible through the practice of cultivation by the site occupants. It is very likely that wild plant gathering was also a common practice, and is indicated by the presence of Zizyphus sp. and other unidentified nut fragments.

The Babar Kot human subsistence system included the use of the millet grain, legumes and oilseeds, supplemented by collected wild plants. It is important to reiterate the economic status of the different crops recovered from Babar Kot, especially the millets Setaria italica, Panicum miliare and Eleucine coracana. Of the three millet crops recovered, Setaria italica was preferred most by the site occupants, followed by Panicum miliare. The millets as a group were the most important crops at Babar Kot and most probably were the basis of their subsistence system. They were most probably cultivated mainly in the summer monsoonal periods of the year.

Linum sp. was also a relatively important plant in the last Late Harappan occupation at Babar Kot occupation III. The oilseed was probably used for human food, and being suitable for cold and warm weather cultivation it added to the diverse nature of the farming system. Even though the leguminous crops such as Lathyrus mungo, Lens sp. and Vicia sp. were not very important as crops (as seen through their degree of recovery), their cultivation is significant since it further illustrates the diverse nature of the Babar Kot subsistence system. Two legumes, Lathyrus mungo and Lens sp., are winter cultivars and their presence is further indication that the Babar Kot occupants practiced year round agriculture.

Preliminary analysis of the faunal assemblage at Babar Kot reveals that animal meat (both domesticated and wild) consumption probably also contributed significantly to the diet of the inhabitants (Ryan 1991). Evidence of domesticated animals in the Late Harappan occupation of the site is strong and includes zebu cattle (Bos indicus), water buffalo (Bubalus bubalis), sheep (Ovis orientalis), goat (Capra aegagrus), pig (Sus scrofa domesticus) and dog (Canis familiaris) (Ryan 1991). A range of wild animal bones (probably hunted for food) were also recovered and include wild boar (Sus scrofa cristatus), nilgai (Boselaphus tragocamelus), chital or spotted deer (Axis axis), blackbuck (Antilope cervicapra), gazelle (Gazella gazella) and four-horned antilope (Antilope cervicapra) (Ryan 1991). Thus, an important component of the subsistence system was the use of wild resources (both plant and animal) by the occupants.

The focus of this dissertation has been plant usage, and therefore the model developed concentrates on the plant usage aspect of the subsistence system at Babar Kot (Figure 7-2). Elucidated in the model are the different processing stages and activities involved in the preparation of millet grain as human food: winnowing I, roasting, winnowing after roasting, pounding/dehusking and winnowing II. The disposal and filtering of the discard and selected seeds (both crop and non-crop) as relevant to this particular site is graphed to illustrate the complexity of the ultimate archaeological picture. Archaeological samples include discard as defacto, primary and secondary refuse in contexts of storage, roasting, cooking and cleaning events. In contrast to the model of plant usage at Oriyo Timbo (Figure 7-1), the Babar Kot model has more activities discerned primarily because of the nature of the site and the character of the subsistence economy. As depicted in the Babar Kot plant usage model there are various plants brought into the settlement (crop plants, wild forage, collected wild plants for food, fuel and building material). However, the treatment of the crop plants is of primary concern, and therefore the model's emphasis is on these plants (Figure 7-2).

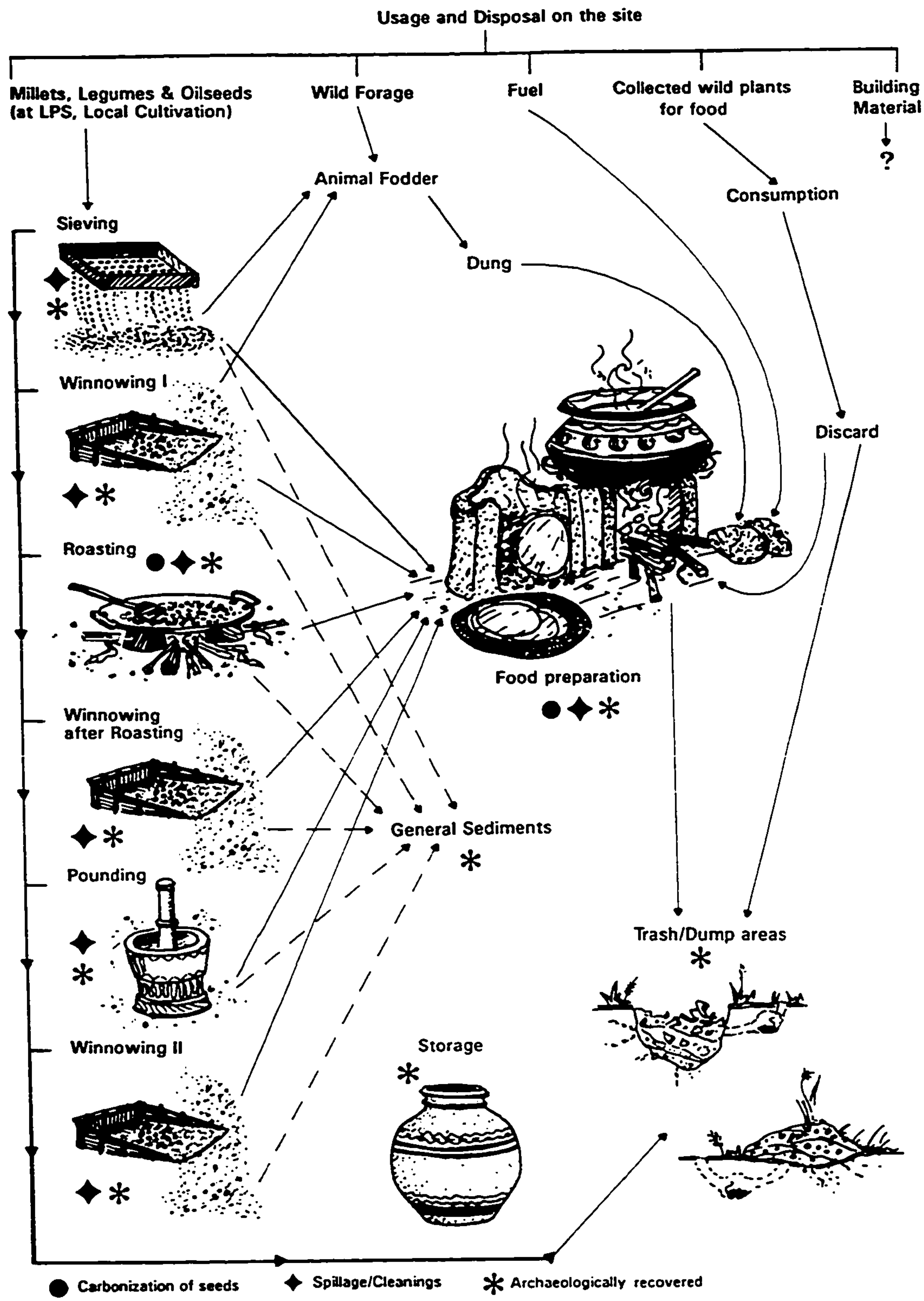


Figure 7-2. Babar Kot Plant Usage Model

The model presents the interpretation that the inhabitants were bringing in Type B millets (Setaria italica and Panicum miliare), legumes and Linum oilseed as lower processing stage products (such as Threshing product) and then completing the consecutive processing stages within the site. Each of the processing stages presented in the model was discerned and identified in different contexts at the site. Other processes, such as sweeping of discard and cleanings into hearths, trash and inclusion into general sediments are inferred based on ethnographic research and the archaeological contextual patterns discerned at the site. The evidence for pounding/dehusking is strengthen by the recovery of grinding stones from the Late Harappan levels. These grinding stones were probably also used to process the grains into flour (after winnowing II process). The processing stages need not have necessarily been occurring in one locale, though there is distinct pattern of higher recovery of lower processing stage components from the slope area of the site. When a byproduct is swept into a hearth and when it is discarded into a trash pit is dependent on several factors; location of the processing activity, distance to the hearth, size of the hearth, time of last cleaning of the hearth and amount of the byproduct to be disposed. Individual occupant variation is a very important factor in the relative role of each of the above factors. Similarly (as discussed in chapter 5) when byproducts from the winnowing I series are given to animals as fodder and when it is discarded is also dependent on various factors. These include amount of byproduct, animal ownership, location of processing activity, location/distance to animals and lastly the subjective measure of necessity for fodder. The use of millet byproducts as fodder was probably prevalent at the site even though it was not observed in the archaeobotanical via dung data. There was a significant quantity of byproduct plant material generated through the processing of Setaria italica and Panicum miliare, and given the presence of domesticated animals at the site the byproducts would have provided valuable animal feed, both as stored and immediate fodder. Millet byproducts

are not an attractive fuel since they burn inefficiently.

The model (Figure 7-2) presents the different plant utilization processes documented to have occurred at the site specifically for millet crops. However, it is important to note that all the processes must have been occurring each year, although how often a process occurs is uncertain. Nevertheless, the presence of these processes confirms the following observations: the status of millets as the primary food crops, oilseeds and linum as secondary food crops and use of wild plants for fuel, food, forage and building materials. Thus, in contrast to the inhabitants of Oriyo Timbo, the Late Harappan inhabitants of Babar Kot were self sufficient agriculturalists practicing year long farming of two (and perhaps three) main millets, oilseeds and legumes and also utilizing and exploiting the considerable wild resources available locally.

Summary of Archaeological Modeling

The ethnoarchaeological and archaeobotanical investigations at Oriyo Timbo and Babar Kot focussed on addressing the economic role of millet cultivation for the occupants. The results reveal that the Late Harappan pastoral nomadic or semi-nomadic pastoral inhabitants of Oriyo Timbo were not cultivating millets at the site. Instead, they were bringing them in at the onset of occupation each season, or, were trading and exchanging for them from neighboring agriculturalists. The character of and patterns in the archaeobotanical data indicate the use of millet grains primarily as human food. In contrast to this situation, the occupants of the Late Harappan sedentary settlement of Babar Kot were involved in year long local cultivation of crops, primarily millets, legumes and oilseeds. The Babar Kot inhabitants were definitely using millet grain as human food, and millets were the primary food crop for the settlement, and therefore an integral component of the economy.

Oriyo Timbo archaeobotanical remains were mainly recovered from secondary refuse contexts such as general sediments and trash/dump pits, and to a lesser degree in primary refuse contexts such as hearths. The Babar Kot archaeobotanical remains were also recovered primarily from secondary refuse contexts (pits, trash dumps and general sediments). However, defacto refuse in the form of pot contents and to a lesser degree primary refuse (hearth contents) was also recovered. Other differences between the two sites included the range of plant remains recovered from the three main cultural contexts. The Oriyo Timbo archaeobotanical assemblages from primary refuse contexts (hearths) show a significantly higher frequency of weed seeds, while Babar Kot primary refuse plant remains consist of higher frequencies of crop seeds with weed seeds accounting for a lower percentage. This distinction is significant and was used to argue for the varying use of the crop plants at the two sites.

Additionally, the recovery of secondary refuse plant remains from Babar Kot was higher than at Oriyo Timbo and this difference might be a reflection of length of settlement occupancy, occupancy numbers and a higher number of processing activities at Babar Kot. The presence of defacto plant remains at Babar Kot is also important since it is indicative of storage. More extensive evidence of storage would indicate a form of long and short term planning and also surplus production. However, these issues remain as speculation at this point. Thus, it is important to note the differences in refuse types, their compositions between the two sites and their application for the respective subsistence economies.

The archaeobotanical and ethnoarchaelogical investigations have successfully addressed the main issues of this dissertation. The Oriyo Timbo subsistence economy was characterized by an absence of cultivation by the site occupants, while the Babar Kot subsistence system was defined through the identification of cultivation by the site occupants. Additionally, the use of millet crops as human food at both the sites was

elucidated, as was the lack of millet use as fodder at Oriyo Timbo. The use of millets as fodder could not be definitively discerned at Babar Kot due to the complexity of the problem. It was, however, proposed that the likelihood of using millet byproducts as fodder by the occupants was very high given the amount of byproduct generated and the presence of domesticated animals. This hypothesis can be strengthen using other lines of evidence, such as bone chemistry and carbon isotope analysis of the domesticated animal remains from the site. The next chapter addresses this line of investigation, its problems and the preliminary results.

CHAPTER 8

MODELING ANIMAL DIET AND FODDER ACQUISITION

This chapter addresses the issues related to the elucidation of fodder and animal diet, specifically at the sites of Babar Kot and Oriyo Timbo. Carbon isotope analysis was chosen as a method for exploring different emphases in fodder, especially between wild forage and millets. Isotope analysis was done on wild forage plants, archaeological sediments and animal bones. The procedure, problems and results of this analysis and subsequently, the ethnoarchaeological investigation of animal dung and its archaeological implications, in the context of archaeological elucidation of fodder, are discussed. In addition, ethnographic observations on forage acquisition and selection by pastoralists are presented. The chapter concludes with the presentation and discussion of an animal feeding model for the Late Harappan of Gujarat.

CARBON ISOTOPE ANALYSIS AND RESULTS

The relative importance of millets (byproducts or green crops) as animal fodder at the sites of Oriyo Timbo and Babar Kot potentially can be elucidated by carbon isotope analysis of animal bones. Ratios of the two stable isotopes of carbon, Carbon 13 (^{13}C) and Carbon 12 (^{12}C) in animal bone collagen have been used to determine the relative contribution of C_4 plants (such as maize and millets) versus C_3 plants (such as wheat and barley) to the diet of the consumer (DeNiro and Epstein 1978; van der Merwe 1982). Millets (such as Eleucine coracana, Pennisetum typhoides, Panicum miliare, Sorghum bicolor, and Setaria italica) are C_4 plants, and if they were the major source of animal fodder, then animals with a diet consisting of a high proportion of plants with C_4 photosynthetic pathways should be reflected in a relatively heavy carbon isotope signature of the animal bone collagen (Deniro and Epstein 1978). The use of 'heavier' to indicate a less negative $\delta^{13}C$ value (richer in $\delta^{13}C$) and 'lighter' to indicate

a more negative $\delta^{13}C$ value (less rich in $\delta^{13}C$) follows the practice of O'Leary (1981:553). Generally accepted $\delta^{13}C$ ranges for C3 plants are -20% to -35%, while the $\delta^{13}C$ ranges for C4 plants are -9% to -16% (van der Merwe 1982). Provided that well preserved bone is available, carbon isotope analysis is ideally suited to determine the extent of millet use during the Late Harappan, because millets were the primary C_4 plants of economic importance in Gujarat.

In general, with respect to the study of Harappan subsistence economy in Gujarat, the exact proportion of millets in animal diets, particularly cattle, is not as essential. Instead, the relative long term changes in the dependence on the different fodders, particularly millets versus wild forage, is of critical importance. An increased emphasis on millets as fodder during the Late Harappan of Gujarat may indicate the emergence of a specialized subsistence system, with animal husbandry as an important and critical variable. This has parallels to present day Gujarat (Reddy 1991). Such a change in subsistence economics, entailing specialized food production and intensification, could have far reaching implications for the Late Harappan period of Gujarat. Increased concentration on fodder cultivation implies more specialized subsistence procurement and in this case a shift from a previous non-specialized procurement system. This research proposed to investigate this inference through the application of carbon isotope analysis of animal bones (specifically cattle) from Late Harappan sites, in order to complement the insights gained from the ethnographic crop processing studies and archaeobotanical analysis of plant remains from Late Harappan sites.

In order to discern the relative importance of millets as fodder versus other wild plants, it was necessary to ascertain two variables: the nature of the environment, and whether other C_4 plants were present which could skew the millet signatures. Soil

samples from the different occupation strata at Oriyo Timbo and Babar Kot were chemically analyzed for soil organic carbon isotope signatures to ascertain the nature of the environment at the time of occupation. It is important to determine whether a C3 or a C4 environment existed locally because this would help elucidate whether C4 plants were dominant. This observation is crucial in establishing millets as primary plants of economic importance. In other words, for this technique to be useful, the local environment should have a different carbon isotope signature than the crops under investigation. Typically, C4 environments are indicative of lower rainfall and arid conditions, while a C3 environment is more indicative of temperate climates. All of the laboratory analyses of soils, plants and bones related to carbon isotopes were conducted by the Paleodiet Laboratory, University of Wisconsin, Madison under the supervision of Dr. Margaret Schoeninger.

A total of nine sediment samples were submitted for analysis, four from Babar Kot and five from Oriyo Timbo (Table 8-1). The $\delta^{13}C$ values of the soil organics in the Oriyo Timbo Harappan levels ranged -18.2% to -22.6%, with an average of -20.4%. This lighter $\delta^{13}C$ value is indicative of a strong C3 signal, thus implying a higher ratios of C_3 plants as compared to C_4 plants in the environment during the site occupation. The Babar Kot soil organics show similar lighter signatures with the $\delta^{13}C$ values ranging from -17.5% to -21.2% in the different strata, with an average of -19.4%. This again indicates a higher percentage of C_3 plants in the environment at the time of occupation. Therefore, the soils from the occupation levels of both sites sampled in this project show a strong C_3 environmental signal, and thus any C4 signature derived from animal bones cannot be attributed to the local environment but rather to specialized feeding.

Along with soil samples, ethnographic samples of wild fodders were collected and analyzed for their carbon isotope ratios. These fodders were specifically analyzed

Table 8-1. Soil Organics of Oriyo Timbo and Babar Kot Soil Samples

SITE	Occupation	δ C13 (%)
Babar Kot	III	-21.2
Babar Kot	III	-20.2
Babar Kot	II	-19.6
Babar Kot	II	-17.5
Oriyo Timbo	II	-18.2
Oriyo Timbo	II	-21.4
Oriyo Timbo	II	-22.6
Oriyo Timbo	I	-18.4
Oriyo Timbo	I	-18.4

because they are currently selectively chosen by pastoralists and farmers as cattle fodder. A total of 19 different wild fodders were analyzed for their $\delta^{13}C$ values. Approximately 70% of them were C_3 plants, and 30% were C4 plants. The $\delta^{13}C$ values for the C_3 plants ranged from -23.9% to -30.5%, and the $\delta^{13}C$ values for the C_4 plants ranged from -10.1% to -12.9%. Some of the C_4 plants such as Trianthema sps, Amaranthus sps and Setaria tomentosa are also prominent field crop weeds. This predominance of C3 plants ethnographically is also corroborating evidence for a local C3 environment in the past since the environment is believed to have been similar to the present specifically during the Harappan phase.

The $\delta^{13}C$ values for soils and wild fodders make the interpretation of the animal bone collagen isotopic ratios relatively straight forward, since there would be limited confusion from other sources of C_4 fodders apart from millets. However, if considerably more C_3 plants were eaten by cattle than the C_4 millets, then the millet signature would be obscured. Thus, one needs to consider the seasonality of fodder availability and the mixed feeding on C_3 and C_4 plants in such an investigation. In

addition to bone preservation in the local sediments and post depositional changes, the chemistry of the animal bone collagen is ultimately dependent on a number of variables. These include the nature of local sediments and vegetation, herding characteristics, nutritive value of forage, forage availability, selection and potential of fodder intake. For archaeological application, only some of these variables can be observed and quantified through ethnographic studies. These include seasonality of fodder, forage nutritive quality and selection by animal and herder.

My ethnographic studies show distinct seasonality in the availability and consumption of fodder by cattle and goats. As just discussed, such selected fodder (for their nutritive quality) were analyzed for their $\delta^{13}C$ values and a significant majority are C_3 plants. These plants are, however, seasonally available, mostly in the winter months. For example, as presented in the earlier chapter discussion of the Oriyo Timbo subsistence system, often wild fodders such as Cressa cretica (a C_3 plant) are preferred over millets and other crops or their byproducts. Cressa cretica is readily available in the winter and enhances milk production in cattle and goats because its high protein content induces lactation. It is used fresh, and when available it is given primary preference, since it cannot be stored as dry fodder.

Carbon isotope analysis cannot recognize seasonality in fodder consumption, because of the fact that bone collagen has a slow turnover rate. But what is of primary concern for questions related to economic importance of millets to the occupants of Oriyo Timbo and Babar Kot is the relative proportion of millets versus the wild C_3 plants in the animal diet rather than the exact amount. Using the data from the wild fodders, the $\delta^{13}C$ values of archaeological animal bones from the two sites can be interpreted as being indicative of a higher proportions of a C_3 versus C_4 diet, or a mix of the two. Although carbon isotope analysis has shortcomings regarding the detection of seasonality and other related processes, the signatures will provide insights into the

long term proportional feeding of C_3 and C_4 plants.

A total of 22 cattle bones were submitted for carbon isotope analysis, 11 from Babar Kot and 12 from Oriyo Timbo. Unfortunately, except for two samples, the carbon isotope analysis of faunal remains from both the sites was unsuccessful because of the poor condition and preservation of collagen in the faunal bones. Two different methods of collagen retrieval were used. The first was the HCL method of extraction using two different techniques; first as done by Deniro and Epstein (1978, 1981) and later improved by Chisholm et. al. (1983) and Schoeninger and Deniro (1984). The other HCl method used was developed by Sealy and van der Merwe (1986). When neither method was successful, extraction through the EDTA demineralization procedure (Tuross et. al. 1988) was employed because they have shown that the yield of collagen obtained through EDTA demineralization was consistently higher than extraction procedures that used HCL. The EDTA extraction method is particularly appropriate for fossil samples with small amounts of organic material (Schwarcz and Schoeninger 1991). Despite these intensive retrieval procedures, collagen was extracted only from two cattle bones, both from Oriyo Timbo strata 6b of occupation I. The $\delta^{13}C$ values of the collagen from these bones was -30.063% and -27.790%, both strong C_3 signals. The soil $\delta^{13}C$ signature for occupation I is -18.4% also a C_3 signal. Of concern are the high C:N ratios of 10 and 8.2 obtained for the two bone samples. The accuracy of the $\delta^{13}C$ signatures of the bones depends on whether the $\delta^{13}C$ values measured intact collagen protein or proteins with amino acids compositions similar to the intact proteins (Schwarcz and Schoeninger 1991). The use of C:N ratios in the past as a screening procedure (DeNiro 1985; DeNiro and Epstein 1981; Schoeninger and DeNiro 1981) has been proven ineffective. According to Schwarcz and Schoeninger, (1991:294) the C:N ratios outside the acceptable range of 2.7 - 3.6 is indicative of non-collagenous

material, however a C:N ratio within the range does not suggest acceptable collagen either. Instead they argue that organic residues should weigh at least 5% of the original bone weight to use the C:N ratios as indicative of non-collagenous material. In the case of the two Oriyo Timbo bones with the ^{13}C values, the organic residues weights were less than 5% of the original bone weight. Therefore, the C:N ratios cannot be indicative of collagenous material and the $\delta^{13}C$ values determined for the two Oriyo Timbo bones must be considered inconclusive.

Nonetheless, even though specific isotopic data are lacking, it is useful to discuss the theoretical implications of various isotopic signatures for understanding the use of different plants as fodder and to reconstruct animal diet during the Late Harappan in Gujarat.

PREDICTIVE MODELING OF ALTERNATE FODDER EMPHASES

It is possible to predict the systems in play if indeed there was a a C3 or a C4 signature determined for the Oriyo Timbo and Babar Kot domesticated animal bones in spite of the failure of collagen extraction and the lack of carbon isotopic data. The two main situations would be either the elucidation of a relatively heavy $\delta^{13}C$ signature (indicating a C_4 plant diet) or a lighter $\delta^{13}C$ signature (indicating a C_3 diet) .

A relatively heavy $\delta^{13}C$ signature from the cattle bones would imply that C_4 plants were consumed in greater proportions. Millets were probably a major contribution to the animal's diet since the majority of wild fodders are C_3 plants and their inclusion into the animal's diet would not confuse the issue. If indeed a heavy $\delta^{13}C$ signature has been obtained, this being indicative of higher consumption of millets, a critical issue would be whether millet grains or millet byproducts were being used as animal fodder.

This distinction is significant since the use of millet grain for animal fodder

would indicate that the crops were primarily grown for animals, whereas using millet residues for fodder implies that the crops were grown for both human and animal consumption. The difference has a significant effect on the interpretation of the subsistence economy. Although it may seem counterproductive to cultivate millets only for animal fodder, ethnographic data from tradition, non-mechanized farmers and pastoralists show that, very often, quick maturing millets are cultivated solely for animals as insurance against lean periods (Purseglove 1979). However, it is important to note that when millets are cultivated solely for animal fodder, they are not allowed to seed, since fresh green fodder is more effective in terms of its nutritive quality, palatability and the digestion and utilization of nutrients. Therefore, when millets are cultivated for animal fodder, the crop is harvested green and fed directly to the animals. In the rare cases when the crop is allowed to seed, the crop is still cut and fed without any processing. In areas of extreme seasonality of fodder availability, the harvested millets crop plants are stored for usage during the lean months. In either case the millets cultivated solely for animal fodder are never processed through the various stages described in chapter 4. This is a very important distinction, and can be used in archaeological contexts to determine whether a crop is cultivated for human food or animal fodder.

Oriyo Timbo and Babar Kot both show a high recovery rate of millet crop seeds from archaeologically distinct contexts related to domestic activities. Presence of seeds in such contexts are therefore indicative of usage primarily as human food since the cleaning of crop products through an intensive processing pathway would not take place if the only intention was use as animal fodder. Additionally, since Oriyo Timbo inhabitants do not appear to have been cultivating millets at the site as determined through the ethnoarchaeological comparison, their access to millets as animal fodder

would have been minimal. Therefore, a $\delta^{13}C$ value with a C_4 signature would indicate predominant selective feeding of C_4 wild fodders. Since the soils indicate a C_3 environment, such a result implies that the Oriyo Timbo inhabitants were controlling and purposely selecting the diet of their animals.

A $\delta^{13}C$ value for the animal bones indicative of a C_4 diet would be easier to explain for Babar Kot than Oriyo Timbo. Crop byproducts at the various processing stages are viable animal fodder, and in the case of Babar Kot where millets were being cultivated by the site occupants (as opposed to Oriyo Timbo inhabitants who appear to have been obtaining the millets through trade and exchange) it is very likely that the crop byproducts from the different processing stages were used as fodder (both immediate and stored) for the domestic animals such as cattle. Several contexts were identified at Babar Kot (and discussed in chapter 7) which are indicative of such processing byproducts. However, one might ask if these assemblages are indicative of cleanings from these processing stages, or if they are indicative of use of the byproducts from these processing stages as fodder, and subsequently included in animal dung used as fuel? The distinction might seem significant, but, for the questions posed in this dissertation, the distinction is not as critical for two reasons. First, to identify cultivation by the inhabitants, the presence of assemblages indicative of lower processing stages (and therefore local cultivation) is in itself sufficient regardless of their context (in dung or as distinct cleanings). Secondly, for the question of use of millets (grain or byproducts) as animal fodder, the presence of the crop processing byproducts in a dung related context strongly supports the hypothesis of fodder use. However, even if dung contexts are absent, the given presence of the byproducts increases the likelihood for their having been used as fodder. The following discussion concerns these issues of assemblages indicative of cleanings from processing stages versus fodder use (and subsequent use of dung as fuel).

Miller (1984) has stressed through her study of dung fueled fire contexts that dung used as fuel can be a source of seeds in fireplaces. Bottema (1984), Miller (1984) and, Miller and Smart (1984) have found carbonized and uncarbonized seeds in modern dung fueled fire contexts. However, there is considerable concern regarding the survival of seeds because of the high temperatures in these contexts (Hillman 1984; Reddy 1991). Certainly, Bottema (1984) and Miller (1984) present viable models for archaeological contexts, given the recovery of dung fuel remnants and high concentration of charcoal (as argued by Miller (1984) for dung fuel contexts). These studies, however, do not address the use of crop processing byproducts as fodder, nor the issue of distinguishing the ingested seeds from the inclusion of byproducts into the dung as temper, or their inclusion into the hearths by disposal during processing and cleaning. The latter two situations were both observed in ethnographic contexts in South Asia. Miller (personal communication, 1990) recognizes that contexts where crop processing residues are tossed into dung-fueled fire as trash create assemblages that are impossible to distinguish from assemblages created by inclusion of seeds into dung as fodder and a later use of the dung as fuel.

Since both the studies of Bottema (1984) and Miller (1984) were in the Near East, an ethnographic pilot study of dung samples and hearth samples was conducted for this dissertation. The objective of the study was to gain insights into the construction of hearths and the formation of hearth contents. This study was built on the work of Miller (1984) and included the study of both the dung cakes which are used as fuel, and the dung fueled contexts such as the ash samples of hearths. The study included a combination of interviewing, mapping of hearths, and collection and analysis of hearth contents. A range of hearths were studied for insight into their construction, including make-shift hearths in the field, make-shift domestic hearths, stationary

domestic dung plastered hearths, and mobile dung plastered hearths. The results and analysis of the dung samples and the hearth contents are summarized below, however the construction of the hearths will not be addressed here.

Ethnographic cattle dung samples analyzed for their composition, were approximately 1.5 litres each and consisted of cattle dung along with millet crop straw used as temper, some non-crop vegetative matter, plant seeds and over two dozen goat dung pellets. A total of four dung samples were analyzed. The plant seeds were comprised of millets, legumes and a range of weed seeds. The cultigens accounted for 2.0%, while weed seeds comprised 98.0% of the plant seeds recovered from the dung cakes (Table 8-2). Three ash samples from hearths where dung was used as fuel were also analyzed. The seeds recovered from these contexts included millets, legumes and weeds, with cultigens accounting for 64% and weeds accounting for 36% (Table 8-2). This latter pattern differs substantially from Miller's (1984) pattern of ethnographic assemblages from dung fueled contexts, since her results had a significantly higher percentage of weed seeds. So, the dung cake assemblage analyzed in this project is similar to Miller's (1984) samples.

Thus, in contrast to Miller's (1984) findings, there is a significant distinction in the composition of the two assemblages; dung cakes and dung fueled hearth samples. There are two major differences, botanical composition and density of seeds recovered per liter (Table 8-2). The botanical compositions of the two assemblages are significantly different, with cultigens comprising the majority of the ash assemblage from the hearth, while in the dung assemblage they occur in very low densities. Weed seeds, however, occur in higher densities in the dung samples but in significantly lower densities in the ashy hearth sample. The reversed ratios of botanical composition are significant for archaeobotanical interpretations related to the origin of seeds (from dung versus from crop processing byproduct disposal). It is possible that the reversed ratio in

Table 8-2. Compositions of Ethnographic Dung and Ash Samples

Absolute Counts

Sample	Volumn	Total seeds	Cultigens	Weeds
Dung Cake	1.5 litres	174	4	170
Ash sample	1.25 litres	31	20	11

Standardized to 1 litre

Sample	Volumn	Total seeds	Cultigens	Weeds
Dung Cake	1 litre	116	3	113
Ash sample	1 litre	25	16	9

the hearth samples is a result of loss of seeds (both cultigens and weeds) from the dung cakes during the fueling process. However, it is more probable that the high frequency of millets in the hearth samples are due to crop processing byproduct disposal. This is further supported by the ethnographic interviews, conducted in this dissertation, which revealed a high incidence of crop processing byproduct disposal (specially from the higher level processing stages) into hearths.

The assemblages from the various contexts at Babar Kot are indicative of both the situations (i.e. some contexts have high percentage of weeds while others have high percentage of millets), and I argue that it is not possible to conclusively distinguish the use of byproducts as fodder (and subsequent use of dung as fuel) and the disposal of byproduct cleaning into various contexts. As stressed earlier, the lack of resolution is not critical, since the presence of the byproducts demonstrates the presence of certain processing stages and through ethnographic observation it is proposed that there is a high probability these byproducts were used as fodder. Additionally, the status of Eleucine coracana at Babar Kot as a primary human crop is questioned, due to its occurrence in very low frequencies. It is hypothesized in this study that the plant crop

might have been cultivated solely as fodder and this may account for the lack of evidence for crop processing stages and the low seed frequencies. Thus, the Babar Kot inhabitants appear to have cultivated Setaria italica and Panicum miliare as human food, while Eleucine coracana was possibly only a fodder crop. The choice of specific crops for different purposes would have been dependent on several factors, including necessity and the success of cultivation.

The implications of a lighter $\delta^{13}C$ (C_3) signature are equally important and have far reaching inferences, particularly with respect to the 'pastoral' character of Oriyo Timbo and the importance of animal husbandry to the Babar Kot occupants. Since the wild fodders in the area appear to be mostly C_3 plants, one can infer that such a pattern is the result of the animal diet being primarily based on wild forage. In the case of Oriyo Timbo, such an emphasis would fit well into their subsistence economy which was based on acquisition of human food grains (such as millets) through trade and exchange. In this situation the Oriyo Timbo inhabitants obtained the primary food grains from outside, and raised their animals on wild forage (through intentional collection and/or free range grazing). In case of Babar Kot, a $\delta^{13}C$ signature indicating that animal diet was primarily based on C_3 plants would be harder to explain. Cultivation of millet crops by the inhabitants would have no doubt generated a considerable quantity of byproduct (from crop processing), and their lack of use as fodder would need to be explained. The deliberate selection against the millet byproducts is unlikely. However, factors that could have been important are seasonal availability of millet byproducts and the quantities available. In such a case, the reliable ratio of C3: C4 plants in the animal diet would need to be examined further.

Nevertheless, if the animals were feeding primarily on wild fodder, then the question arises whether a sizable herd really could be maintained in the environs around Oriyo Timbo and Babar Kot. This would be particularly problematic during the lean

dry periods of the year. Therefore, in the case of Babar Kot, herds may have been taken to other locales during the dry season. This solution is not applicable for the Oriyo Timbo inhabitants since they occupied the site during the dry season. Therefore, they must have survived on local fodder acquisition. These issues can be examined only when further conclusive carbon isotope data on animal bones is available.

ANIMAL FEEDING MODEL FOR GUJARAT HARAPPAN

Based on the available information (ethnographic, archaeological and theoretical isotopic signatures) a predictive animal feeding model for the Late Harappan in Gujarat is proposed (Figure 8-1). The model is specifically intended for domesticated herbivores, such as cattle, pigs, goats and sheep, all of which are present at the sites of Oriyo Timbo and Babar Kot.

The animal feeding predictive model can be employed when isotopic data from animal bones are available, and at that time the various implications of the isotopic data can be interpreted. For example, if a C_3 signature is obtained for the animals bones, the model can be used to argue for specific selective and natural processes effecting the diet which ultimately produced the specific signature for the animal. Since it was intended for this purpose, the dietary effects on animal collagen is the major focus of the model. Even though the animals considered in the model are domesticated, their feeding behavior is not random, instead it is a highly selective and distinctive activity.

The model presents six different factors that effect fodder choice: whether the animal is going to feed primarily on millets (green crop or byproducts) or wild forage (collected or free range) (Figure 8-1). The factors are level of intake, herd effects, potential intake, nutritive value, selection and economy. The relative importance of each factor is determined by several conditions. The level of intake is primarily effected

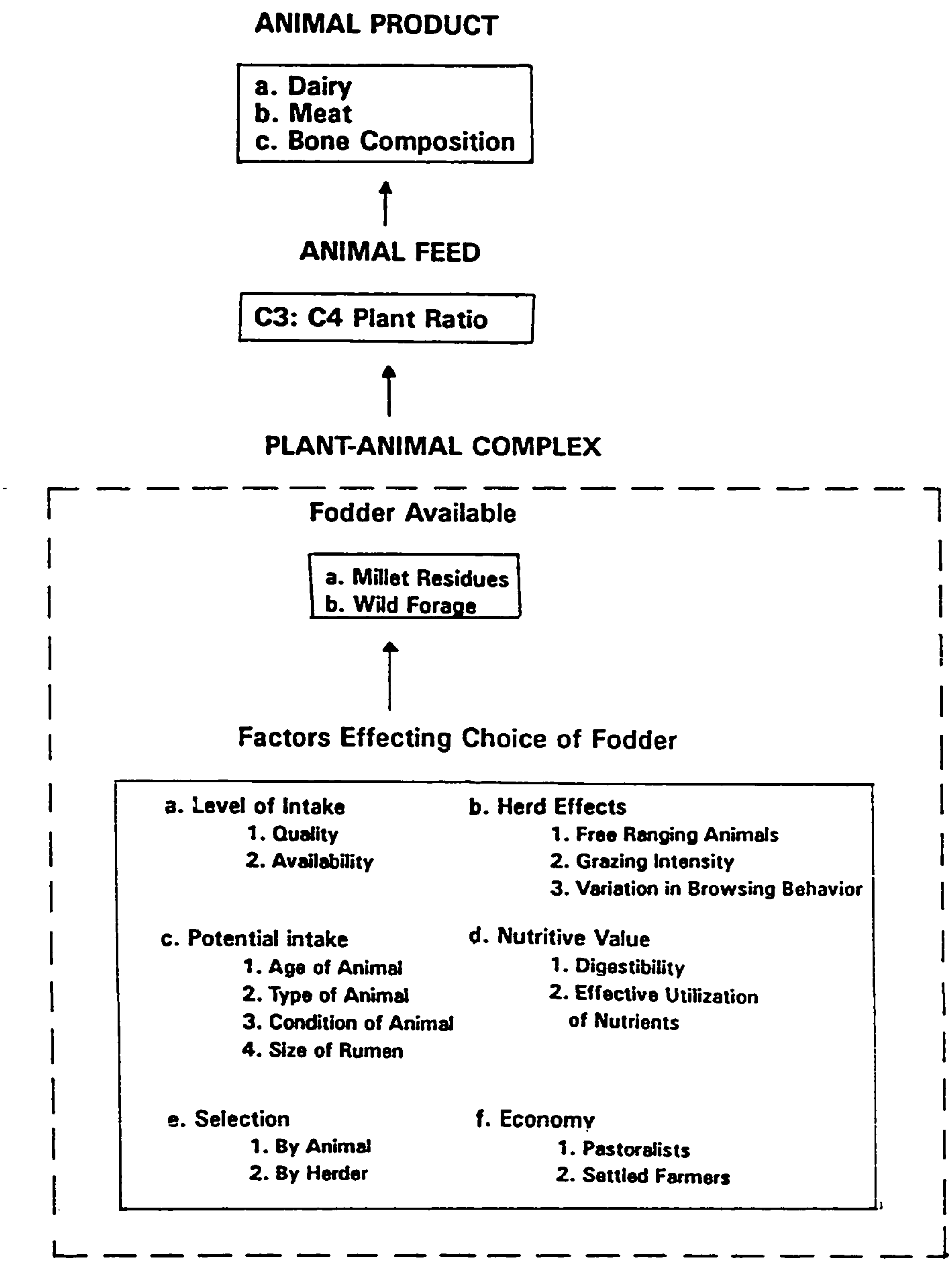


Figure 8-1. Domesticated Herbivore Feeding Model for Late Harappan of Gujarat, India

by the quality (and therefore the palatability) of the available fodder (fresh or dried), and also the seasonality in the availability of different fodders. Potential intake is an animal dependent variable, indicating that the physical condition of the animal effects the choice of fodder. Nutritive value of the fodder can be seen as a determining factor in the choice particularly for the wild forages. Caswell et al. (1973) conducted a study of herbivore diet selectivity and photosynthetic pathways, and proposed that the C_4 wild plants in general have a lower digestibility, palatability and nutrient value due to inherent photosynthetic processing locations. This implies that digestibility and effective utilization of nutrients in herbivores is higher for C_3 plants than C_4 plants (Caswell et al 1973; Wilson and Ford 1971). Their study was conducted on grasshoppers, and it is not certain whether the results are applicable to domesticated animals, specifically ruminants like cattle. They also proposed that herbivores avoid C_4 plants rather than prefer C_3 plants. If this assertion is correct, then the nutritive value choice of wild forage would be selectively biased toward C_3 plants.

Herd effects also determine the mix or dominance of millets versus wild forage in the animal diet. The main herd effects of concern are grazing and browsing. Browsing, which entails feeding on scanty vegetation, is very common in Gujarat. However, browse vegetation is usually fibrous and contains tannins (essentially oils and other aromatic compounds) that decrease palatability. In addition, browse plant species are of low palatability and eaten primarily in the dry season when herbaceous forage becomes either sparse or unpalatable. Grazing entails eating grasses and woody materials. Animal species differ in their preference for browsing and grazing, with sheep and cattle, being primarily grazers, and eating little of the browse type plants. It is quite likely, however, that the zebu cattle graze to a lesser extent. Goats are often considered intermediate feeders, with browsing being the most common feeding method combined with occasional grazing. There is seasonality in the digestibility of

herbaceous grazing forages but not in browsing, which is an important distinction to consider in the model.

Conscious fodder selection by the animals and the herders is another important factor directly effecting whether or not millets or wild forage are dominant in the animal diet. For example, there is selective fodder acquisition by pastoralists, dependent on the effect the fodder has on milk production. The ethnographic and isotopic studies in this dissertation have determined that the wild forage collected by pastoralists shows a clear dominance of C_3 plants. Diet selection by the animal is fundamentally a behavioral process that constitutes the interface between the free-ranging animal and the plant community upon which it feeds (Heath et. al. 1985). While the existence of linkages between diet selection and nutritional status of the animal are obvious, the components and dynamics of these linkages are exceedingly complex and inadequately understood. In spite of the research efforts there is little known about the predictability of nutritive composition and diet selection in a given set of circumstances (Health et. al. 1985). Nevertheless, diet selection (on the part of the animal and the herder) is a recognized behavior which needs to be considered when determining which plant groups (millets or wild plants) dominate the animal diet.

The last factor that influences the choice of millets or wild plants in the animal diet is the subsistence economy of the social group whose animals are being considered. For a community involved in farming and cultivation of millets on a regular basis (such as at Babar Kot), millet byproducts as fodder are readily available. It is highly probable that animals are frequently fed on the residues, particularly in months when wild forage is scarce or free range grazing is not viable. Additionally, some millets might be selectively grown only as green fodder. In such a context, determining the proportion of millets and their residues in the animal diet is of critical importance. This can be

answered only through carbon isotope analysis of the animal bones. In contrast, a nomadic pastoralist community (such as at Oriyo Timbo) focussed on animal husbandry and involved in the procurement of millets from outside primarily for human consumption is unlikely to have millet residues available on a regularly basis to feed the animals as fodder. Whether or not millets (green fodder or residues) are obtained for fodder from non-local sources is dependent on several factors such as the season of occupation (since millets are summer cultivars) and the availability of wild forage. Again, the critical question regarding what proportion of the animal's diet are millets (green fodder or residues) can only be determined through carbon isotope analysis.

The various components of the animal-plant complex in the model (Figure 8-1), directly effect the C_3:C_4 animal feed ratio. The plant ratio is likely to change seasonally, and over the life-span of the animal, and since collagen has a slow turnover rate what is discernible in the bone collagen are the diet ratios in the last years of the animals diet. When carbon isotope data are available for the Gujarat Harappan sites, the model can be put to effective use to interpret the significance of the signatures. In summary, it is proposed that the diets of the Oriyo Timbo domesticated animals were primarily comprised of wild forage, while the Babar Kot domesticated animals were fed millet byproducts when available (November onwards), and wild forage supplemented their diet during other seasons. The next chapter addresses the broad implications of these results to the Gujarat Late Harappan subsistence systems.

CHAPTER 9

MODELING HARAPPAN SUBSISTENCE SYSTEMS IN GUJARAT

This chapter presents the paleoethnobotanical results in the context of their broader implications for the Late Harappan subsistence and settlement patterns in Gujarat, India. To do so, it is necessary to briefly review the archaeological context relevant to the main objectives of this research.

The Late Harappan phase in Gujarat witnessed a proliferation of settlements in arid locations along with a decrease in average site size (Bhan 1989). This proliferation has been attributed to a shift in land use and increased mobility as a result of an increase in pastoralism and the cultivation of millets (Bhan 1989; Possehl 1986; Rissman 1985). Although this hypothesized correlation of settlement proliferation to a revival of a pastoral economy or/and cultivation of millets is intriguing, I argue that simply suggesting that they are the prime explanations for the Late Harappan phenomenon is too limited and the problem needs further clarification.

I suggest that the Late Harappan in Gujarat did not witness a simple increase in pastoralism and a corresponding dichotomy between pastoral and agricultural economies. Instead, these economies became more tightly integrated resulting in a broad spectrum of economic choices. Since no artifactual ties have been noted between pastoral and agricultural settlements (Bhan 1989), investigation of material cultural is currently a nonprofitable line of research. Instead, economic indicators, such as presence or absence of cultivation, provide the best line of evidence to understand the range of possible integration between pastoralism and agriculture during the Late Harappan. Different settlements can be classified as occupied by pastoral nomads or agriculturalists, or by populations practicing subsistence strategies that fall between these two extremes (such as semi-nomadic or semi-sedentary pastoralists). The key issue is to understand how and to what degree particular cultivated products might fit

into pastoral adaptations (Khazanov 1984). Khazanov's (1984) classification of pastoral adaptation, based on the degree of dependence on agriculture by pastoralists is well-suited in examining the Late Harappan of Gujarat. For this investigation of the Late Harappan phenomenon, the elucidation of the usage of millets and/or their cultivation at seasonal pastoral camps (such as Oriyo Timbo) and sedentary communities (such as Babar Kot) provides the strongest lines of evidence.

As mentioned in chapter 2, Bhan (1989), Herman (1991) and Rissman (1985) have each constructed viable arguments for explaining the Late Harappan phenomenon in Gujarat. Several issues, however, remain unaddressed and unresolved. First, why there is an increased need for the maintenance of herds and a shift to a pastoral economy in the Late Harappan of Gujarat, specially since there is no compelling evidence for environmental degradation or failure of farming practices. Second, the social, economic and scheduling implications of millet cultivation by Late Harappan pastoral groups are not addressed. It is possible that a simplification in the socio-political systems in the second millennium may have biased scholars (Bhan 1989; Rissman 1985) to suggest that there was a shift from a sedentary farming economy to a simplified pastoral nomadic based subsistence system. I want to emphasize that even though there is evidence of increased mobility and dependence on herding, the resulting subsistence strategy does not have to be pastoral nomadism exclusively. Variants of these systems, such as cultivators and pastoral nomads complementing each other or cultivators also being pastoralists are important possible adaptations to consider in the elucidation of subsistence and settlement systems. Additionally, Rissman's (1985) use of the term 'pastoralism' is not clearly defined in terms of an integration between pastoral and agricultural economies and he may actually be arguing for a lifeway somewhere along the gradient between pastoralism and sedentary agriculture.

Rissman's definition of pastoralism is based on mobility and he addresses the adaptation as migratory pastoralism.

Therefore, given the complex nature of the issue, one could propose several different explanatory models for the second millennium adaptations in Gujarat. I propose that the breakdown in the Harappan integration sphere around 2000 B.C. resulted in more flexibility in settlement patterns, which included higher mobility of certain groups. In the previous highly integrated Mature Harappan period where socio-political control was centralized at few urban sities, the settlement locations were very likely to have been determined by trade routes and distance to the major centers. The breakdown of the Harappan integration sphere and the socio-political control included the disruption of the trade networks and abandonment of major centers. The resulting system of the Late Harappan was one of localization with local trade centers being the focus of the cultural interaction as opposed to the wide intra-regional integration of the Mature Harappan (Kenoyer 1991). This localization opened up areas previously not occupied, and with millets (established in the region as major crops from the mid-third millennium B.C.) as the basis of the farming economy, the settlement of arid areas in Saurashtra and North Gujarat was accelerated (Bhan 1989; Possehl 1986). The cultivation of millets, which are summer and drought resistant crops, would have facilitated expansion into the arid regions of Gujarat. The model developed in this dissertation for the Late Harappan of Gujarat entails an increased integration of agriculture and herding (as compared to the Mature Harappan), resulting in either semi-nomadic or semi-sedentary pastoral system. In general, such an integrated system possesses favorable risk-reduction characteristics when compared to a specialized subsistence system. Herman (1991) notes that there was increased interaction regionally within Gujarat (between Kutch and Saurashtra) as the greater Indus interaction sphere deteriorated starting 2000 B.C. Thus, the increased integration of agriculture and

herding in the Late Harappan could be a risk reduction adaptation due to the disintegration of trade and exchange within the greater Harappan interaction sphere around 2000 B.C (see also Kenoyer 1991; Meadow 1989).

In order to better understand why this proposition (an integrated economy of pastoralism and agriculture during the Late Harappan in Gujarat) is appropriate, explanations for the proliferation of pastoral adaptations in other regions of the globe need to be examined. The explanations for the origins of specialized nomadic pastoralism are numerous, so specific attention is given to the exemplary models of Lees and Bates (1974), Adams (1974) and Lattimore (1962). These models are appropriate because they specifically address Old World complex societies and the proliferation of nomadic pastoralism, and thus complement this dissertation. The systemic model of Lees and Bates (1974) argues for a direct relationship between the development of nomadic pastoralism as a specialization involving substantial populations, and the development of canal irrigation. They assert that selective pressures for specialization in nomadic pastoralism arises from the practice of canal irrigation as a technique of agricultural intensification. Essentially, their argument rests on the premise that agricultural intensification through canal irrigation, in certain environments, leads to increases in labor input and energy investment with a decrease in agricultural productivity. Thus, the balance between the labor input and agricultural output becomes unfavorable, and alternative strategies are explored by segments of the population, and an obvious alternative being nomadic pastoralism. Adams (1974) argues for a dynamic interaction between pastoralism and irrigation agriculture with the former subsistence mode becoming increasingly important as agricultural yields decline in Mesopotamia. Lattimore (1962) presents a different but related model for this relationship in China.

These models for the proliferation of pastoralism though applicable to most contexts, are not appropriate to the Late Harappan of Gujarat for several reasons, most importantly because there is no evidence of agricultural intensification, specifically through canal irrigation, at the start of the Late Harappan phase. However, they can be utilized to gain a better understanding of the Late Harappan pastoral adaptations. So, given that there is no evidence for agricultural intensification (or failure) as seen in the previously discussed cases, it is argued that the proliferation of pastoralism during the Late Harappan in Gujarat is not simply the result of subsistence and economic factors. Instead, I propose that socio-political factors are just as important, if not more critical, to the proliferation of pastoral adaptations in the Late Harappan phase in Gujarat. Of course the subsistence economy goes hand in hand with the socio-political elements of a society.

Adams (1978) has argued that stabilization of control is a major object of any ruling elite, and Yoffee (1977) has asserted the importance of legitimizing political authority to establish centralized control. Applying this to the Harappan phases of Gujarat (and South Asia), I argue that during the highly integrated Mature Harappan phase when there was strong centralized control on the socio-economic and political spheres, settlement locations and population movements were controlled. In a urban state with centralized control, like the one in the Indus Valley, fluid movements of populations (such as those of the pastoral groups) may have been discouraged to ensure authority of ruling elite and limit local particularlism. The extent of discouragement has to remain a speculation. With the breakdown of the Harappan state (and its centralized control) these discouragements were minimal and therefore the proliferation of pastoral adaptations was viable. So, the argument is that socio-political factors were more critical as compared to subsistence/economic factors, in the proliferation of pastoral adaptations in the Late Harappan. However, they were not exclusive of each other, and

most likely both contributed to the resulting Late Harappan phase settlement and subsistence systems. It is important to note that the proliferation of pastoralism in Gujarat during the Late Harappan was not a sudden consequence (as the cases were for the models proposed by Lees and Bates 1974 and Adams 1974). Instead, I argue for a gradual development/proliferation of pastoral adaptations as the centralized control diminished in the Harappan state towards the end of the Mature Harappan phase.

The main focus of this dissertation has been to elucidate the economic importance of millets (and their cultivation) to Late Harappan pastoral communities (such as those represented at the site of Oriyo Timbo) and settled farming communities (such as Babar Kot). Defining the role of millets (and their cultivation) as animal fodder during the Late Harappan at the sites of Oriyo Timbo and Babar Kot has aided in clarifying the interplay and integration between pastoral and agricultural economies during these times.

The paleoethnobotanical investigations at the Late Harappan sites of Babar Kot and Oriyo Timbo in Gujarat, India, entailed the elucidation of their subsistence economy in terms of local cultivation of millets/crops versus obtaining them through trade/exchange, use of millets as food, fodder or both, and finally a model for plant usage at each site. Each of these are instrumental in determining the degree of the integration of agriculture and pastoralism in the subsistence economies.

At Babar Kot, local cultivation of millet crops by the site occupants was important, and millets were the primary food grains. The practice of sedentary agriculture was supplemented by sedentary animal husbandry, as evidenced by the significantly high recovery of domesticated animal remains such as cattle, goat, sheep and pig. Given that millet cultivation was a prominent activity and that domesticated animals were a significant commodity, the use of millet byproducts as animal fodder is

highly probable, although wild fodder continued to be an important supplement. Additionally, Babar Kot was primarily a non-specialized settlement (unlike specialized Harappan sites such as Kuntasi in North Gujarat, Nageshwar in Saurashtra, or Oriyo Timbo), and the cultivation of cereals for consumption would have been crucial, since they would not be able to trade/exchange for food grain.

Given these results, several conclusions can be drawn regarding Babar Kot and its implications for Late Harappan sedentary communities in general. Cultivation of millets was an integral part of the subsistence economy at Babar Kot, and one can predict that sites of comparable features and in analogous settings in the area had a similar economy. However, the subsistence economy was not concentrated exclusively on cultivation, since wild plant and animal exploitation were significant components of the subsistence strategies, as was animal husbandry. The wide scope of the subsistence economy (ranging from farming, animal husbandry to wild plant and animal exploitation) is an important feature of Babar Kot, which was mostly probably similar to the subsistence economies of other Late Harappan sedentary non-specialized communities. Of interest is the range of millets utilized at the site, which could be indicative of their differential use. Babar Kot millet cultivars included Setaria italica, Panicum miliare and Eleucine coracana, of which the last one had limited use as human food. The latter was probably only used as animal fodder, and cultivated specifically as green fodder (see Chapter 6).

The specialized use of particular crops is of great significance, and suggests a certain degree of complexity in the subsistence practices in terms of long term planning and specialized cultivation. For example, there is a great range in the millets recovered at the site of Rojdi, and of equal importance is the changing emphasis on different millets over time (Weber 1989). Eleucine coracana and Panicum miliare occur prominently in Rojdi A and B but decline in Rojdi C, while Setaria sps and Trianthema

sps are most dominant in Rojdi C but occur in very small numbers in Rojdi A and B (Weber 1992). This temporal change could be reflective of changing demands in the community, such as an increasing importance of millet byproducts or green millet crop for fodder. Such demands would necessitate the selection for millets which have a higher percent of vegetative parts (to get higher mass of vegetative green fodder or byproduct). So, at Babar Kot there might have been a greater emphasis on Eleucine coracana, as compared to the other two millets, as green fodder for animals. Therefore, at Babar Kot, the cultivation of millets as animal fodder (even minimally) and human food is suggestive of an economy more akin to sedentary agriculturalists, with a very minor pastoral component, that of sedentary animal husbandry. It is conceivable that a separate group (an ethnic community distinctive from the farming segment) within the entire Babar Kot community were the only portion of the population practicing pastoralism. However, there is no evidence currently, archaeological or paleoethnobotanical, to support such a possibility.

At Oriyo Timbo, local cultivation of millets by the occupants was not identified in the paleobotanical analysis. Instead, the millet grain were brought into the site as highly processed grain obtained either through trade or exchange with farming groups in the area, or cultivated elsewhere (outside the range of the settlement) by the occupants and brought along with them to Oriyo Timbo on their seasonal migrations. These observation are supported by the seasonality data from the annuli ring study by Rissman (1985) that places the occupation of Oriyo Timbo during the months of March through July. Thus millet cultivation by the occupants is further improbable, since the growing season of traditional millets is August through November. Only the modern genetically altered strains are viable for winter cultivation.

Since the Oriyo Timbo archaeobotanical assemblage does not include any

millet byproducts assemblages, their use as fodder is improbable. Fodder for domestic animals would have comprised of wild forage selectively collected by the herders, or alternatively the animals could have been grazed and browsed freely. The human plant diet at Oriyo Timbo therefore included the use of millets and legumes, but was heavily supplemented by the collection of wild plants. Animal consumption (both wild and domesticated) also was an integral part of the subsistence strategies.

Given these conclusions, several broad implications can be drawn from Oriyo Timbo with respect to Late Harappan seasonal communities with pastoral adaptations. The subsistence economy of Oriyo Timbo can best be described as a form of semi-nomadic or semi-sedentary pastoralism, especially because it is possible that the occupants may have practiced millet cultivation elsewhere during other seasons. In the case of a semi-nomadic pastoralist economy, Oriyo Timbo inhabitants would have been primarily focussed on animal husbandry and pastoral economy, but also conducted small scale agriculture. Alternatively, in the case of a semi-sedentary pastoral economy, the occupants primarily practiced agriculture elsewhere (outside the region) but were also involved in pastoral activities seasonally at Oriyo Timbo.

It is important to stress that the subsistence economy at Oriyo Timbo was not exclusively focussed on animal husbandry, since wild plant and animal exploitation was a significant component of their subsistence strategies. Therefore, in spite of the specialized economy, their subsistence base was relatively diverse. It is suggested that sites similar to Oriyo Timbo during the Late Harappan might have also shared a similar semi-nomadic or semi-sedentary pastoralist economy. It is important to reiterate that it is crucial to elucidate the integration between agriculture and pastoral economies. This interrelationship is especially significant with respect to the possibility of a revival of a pastoral economy during the Late Harappan (as argued by Bhan 1989 and Rissman 1985).

On a broader regional level, the results from the ethnoarchaeological and paleoethnobotanical study at Oriyo Timbo and Babar Kot have important implications for the interpretation of the Late Harappan subsistence systems and settlement patterns. Bhan (1989) suggested that the Late Harappan in Gujarat shows a development of two different categories of settlements: abundant small settlements with simple round huts, most often interpreted as small villages or dry season pastoral camps, and larger sedentary farming settlements with more permanent architecture. Artifactual ties between these two categories of settlements are absent at present, however this two tier system has interpretive implications particularly if there are functional differences - the smaller possible seasonal settlements being pastoral and the larger sedentary settlements are agricultural.

A model of Late Harappan settlement in Gujarat can be developed by applying the detailed results of this dissertation to regional settlement and subsistence systems. This model utilizes Bhan's (1989) two category settlement distinction. The two categories of settlements (the small seasonal sites such as Oriyo Timbo and Ratanpura, and the larger permanent settlements such as Babar Kot and Rojdi) are interpreted as being integrated into a regional interaction sphere. Three main alternative or complementing systems are suggested based on the interaction between pastoral seasonal camps and sedentary agricultural settlements. This model utilizes the observations and distinctions of pastoral adaptations made by Khazanov (1984) with the degree of integration between pastoralism and agriculture as distinguishing parameter between various adaptations, and also the ethnographic study of pastoral groups conducted in this dissertation (chapter 7). In addition, the model is thorough in the consideration of both sedentary and pastoral settlements, since it was argued by Khazanov (1984) and Bar-Yosef and Khazanov (1992) that the existence of an outside

sedentary world is essential for the biological and economic survival of specialized pastoralists.

The first potential system of interaction considers the two types of archaeological sites as formed by agricultural groups and the various forms of pastoralist groups that are separate and distinct populations settling the region. In such a system, there would have been minimal integration between the different settlements. For example, there would be no integration in terms of settlement locations between the pastoral occupants of Oriyo Timbo (and analogous sites) and agricultural occupants of Babar Kot, Rojdi and other analogous sites. However, economic interactions between the two groups, in terms of trade and exchange of perishable and non-perishable items, undoubtedly took place. Therefore, the Late Harappan landscape in Gujarat, comprised of distinct and independent settled agriculturalists involved in economic interaction (trading and exchanging) with each other and with the various forms of pastoralist communities. In such a system, there would be minimal archaeological artifactual ties between the different groups, especially if they are ethnically distinct populations. It is predicted that such a system would entail different annual cycles for the various pastoral groups with distinct sets of sites reflecting independent cycles.

The second system in the model for Gujarat Late Harappan is more complex and involves agricultural and pastoral sites tied together as one settlement pattern. In this system the small seasonal pastoral camps were components of the larger sedentary settlements systems (possibly distinct ethnic groups within a larger population). For example, the former may represent specialized groups such as semi-nomadic pastoralists within a larger community of settled agriculturalists conducting seasonal movements. Thus in a sense, the semi-nomadic pastoralists were a subset of the larger population composed predominantly of agriculturalists. The semi-nomadic pastoralist's economy was dominated by pastoralism while agriculture is secondary. The dynamics

of this system would have involved two different segments (most likely ethnically distinct) in the community, one involved in an agricultural economy and the other involved in pastoral economy primarily, with agricultural playing an occasionally secondary role on a seasonal basis. Identification of such a system requires the identification of artifactual ties between the two different types of settlements (small seasonal camps and permanent settlements), and the identification of the pastoral component (at some level) within the permanent larger settlements. Since there is currently no archaeological data which supports these patterns, the suggestion has to remain speculative at this point.

The third system is more complex and involved semi-sedentary pastoralists as a distinct smaller group within a larger sedentary settlement. In a semi-sedentary pastoral economy, agriculture is the dominant activity with pastoralism being practiced by specialized groups (Khazanov 1983). For example, Babar Kot would be interpreted as a settlement with a majority of the occupants involved in an agricultural economy, and a separate group which also practiced pastoralism on a limited and seasonal basis. Pastoralism as a seasonal activity was most probably reserved for certain segments of the population (by ethnicity, gender or age). In this case, the semi-sedentary groups are a subset of the larger population which are predominantly agriculturalists. Thus, the occupants of the seasonal site of Oriyo Timbo were part of a larger sedentary settlement situated elsewhere, and were involved in seasonal migrations, returning to the 'base' settlement where they maintained annual residence.

To summarize, these three alternative settlement and subsistence system models proposed are primarily differentiated on the basis of the degree of reliance on agriculture by pastoralists and the relationship between pastoralists and agriculturalists. To define such systems archaeologically, it is imperative that cultivation and

processing of crops (if any) including their growing seasons (as an economic activity) is elucidated at a given settlement. However, in addition to cultivation there are several other parameters that are indicative of the different pastoral adaptations, since cultivation is practiced to varying degrees depending on whether the adaptation is semi-nomadic or semi-sedentary pastoralism. These include seasons of occupation, site size, permanence and style of architecture, layout and organization of the settlement (especially intra-site patterning to identify ethnically distinct groups) and artifact density. Additionally, the diversity of site types within the settlement system will be a reflection of different adaptations. For example, in a system where there are limited variations in adaptations (involving only sedentary agriculturalists and herdsman husbandry pastoralists) there is little settlement diversity consisting only of permanent agricultural settlements and uniform pastoral camps. Typically settlements of herdsman husbandry pastoralists have minimal architectural preservation and low diversity in artifact categories, while the sedentary agricultural settlements would have high architectural visibility including substantial structures and a wider range of artifact categories. In contrast, a settlement system with a more diverse range of groups including either semi-sedentary or semi-nomadic pastoralists will have a greater diversity of site types. These sites will have different seasonal indicators with respect to the nature of the architecture, site size, the degree of animal culling and so on.

The presently available archaeological data (archaeobotanical, settlement and culture historical developments) is not detailed enough to definitely support any of the proposed models for the Late Harappan settlement of Gujarat. I would predict, however, that the settlement and subsistence system most likely in play was the first model where there was economic interplay between agricultural settlements and the different forms of pastoralists but limited social integration. This inference is based on several patterns emerging from the archaeological data.

First, there is a lack of artifactual tie/link between the two major site categories (Bhan 1989; Rissman 1985) and this suggests it is unlikely that the two site categories were linked within one annual settlement system.

Secondly, there is considerable diversity in site types with both sedentary agricultural settlements (such as Rojdi, Babar Kot, Rangpur IIB/C and III) and varied sized small rural or seasonal pastoral camps (such as Oriyo Timbo, Kanewal and Vagad). The key pattern is the potential difference between small rural settlements and pastoral settlements. Although there is a lack of resolution, it suggests the potential for a second settlement pattern, socially and economically independent of the larger sedentary agricultural settlements.

Third, based on the results from Oriyo Timbo, where there was an absence of cultivation by the occupants, some of the small pastoral settlements could have been occupied by semi-sedentary or semi-nomadic pastoralists with no definitive social links to settled agricultural communities in the region. Certainly, this issue needs more investigation, and determination of cultivation (its absence or presence) at the various settlements defined as small villages or pastoral camps is imperative for the further understanding and defining of the Late Harappan 'pastoral' groups in Gujarat.

In summary, I argue that the proliferation of the Late Harappan settlements in Gujarat is most probably through the use of pastoralism and agriculture as complementing and not alternative economies. With the decentralization of the Harappan state in the early second millennium B.C., there was decreased control on settlement locations and population movements as a direct result of the break down of the wider integration sphere. At the same time there is increased interaction and integration within the Gujarat region as a result of the decentralization of the greater Indus region (Herman 1991). I assert that these developments allowed for a wider range

of choices of economic adaptation and particularly facilitated the integration of two distinct economies, agriculture and pastoralism, in a semi-arid environment. The cultivation of versatile, drought resistant and short maturation crops such as *Eleucine coracana*, *Panicum miliare* and *Setaria italica* facilitated the success of this adaptation. Of particular importance is the idea (originally proposed by Khazanov 1983) that pastoral adaptations are often usually integrated to some degree with agriculture. The absence of evidence for a failure in farming systems or an environmental degradation during the Late Harappan of Gujarat further decreases the likelihood of a complete shift to nomadic pastoralism or migratory pastoralism as argued by Rissman (1985).

Future research must aim at attempting to understand broader settlement pattern relationships and the interplay between agricultural and pastoral settlements within the Late Harappan of Gujarat. Of particular importance and potential (as demonstrated in this dissertation) is the use of archaeobotanical data and ethnographic models to determine where or not cultivation was practiced at small villages and pastoral settlements. A more detailed understanding of the complementary relationship between agricultural and pastoral economies will emerge by combining these data, with information on seasons of occupation, the patterns and similarities in artifact sets between agricultural and pastoral sites, and intra-site residential differences at the larger sedentary settlements.

CHAPTER 10

CONCLUSIONS: PLANT USAGE AND SUBSISTENCE IN THE LATE HARAPPAN OF GUJARAT

The objective of this dissertation has been to elucidate the economic role, importance and cultivation of summer crops, specifically drought resistant millets, in pastoral and settled farming communities during the Late Harappan phase in Gujarat. This has been undertaken through ethnographic modeling of plant processing and detailed archaeobotanical investigations at two sites. In the early second millennium B.C. (the Late Harappan phase) proliferation of settlements in arid regions has been explained as a result of increased mobility due to a revival of pastoralism (Bhan 1989; Rissman 1985) and/or cultivation of millets (Possehl 1986). I have argued in this dissertation that a total abandonment of agriculture in favor of pastoralism was unlikely. Instead, an integration of the two economies was more probable, and up till now, investigations of Late Harappan subsistence systems have ignored the implications of such a mixed economy. The results of my research at two Gujarat Late Harappan sites, the sedentary community of Babar Kot and the pastoral camp at Oriyo Timbo, provide new insights that support this interpretation.

Another concern of this dissertation has been to determine if there was increased cultivation or use of millet plants for animal fodder during the Gujarat Late Harappan. In particular, this entailed examining the possibility of the use of millet byproducts or millet grain as fodder in 'pastoral' settlements (such as Oriyo Timbo) and sedentary farming settlements (such as Babar Kot). The results from this line of investigation indicate that the interplay and the integration between pastoralism and agriculture during the Late Harappan times was quite complex, and that particular millets played different roles with respect to fodder use.

The results of this dissertation also contribute significantly to two broad domains of archaeological studies: (1) ethnographic research, methodology and modeling; and (2) paleoethnobotanical reconstruction. The main results in each domain and their wider implications to Late Harappan studies in South Asian Archaeology, and to archaeology in general are summarized below.

ETHNOGRAPHIC CROP PROCESSING AND MODELING

Prior to this dissertation, cultivation of the millet crops as a distinct economic activity had not been clearly demonstrated at any Harappan site in Gujarat. The identification of actual cultivation is important in order to exclude the possibility that millet crop grains were being obtained through trade and exchange. To achieve these results, a study and ethnographic modeling of millet crop processing for archaeological application was conducted (chapters 4 and 5). Ethnographic observations of plant processing particularly designed for archaeobotanical interpretations (as done in this dissertation) are rare with the exception of Hillman (1981, 1984) and Jones (1987), and have never been done in a South Asian context or for millet crops. As such, this aspect of the dissertation represents an important and significant contribution to paleoethnobotanical research.

The results of the ethnographic millet crop processing study (chapter 4) are twofold: first, there are distinct variables which can be isolated and used to distinguish the various processing stages; and second, there is a significant difference in processing pathways between the millets crops studied (Type A crops, Sorghum bicolor and Pennisetum typhoides; Type B crops, Panicum miliare and Setaria tomentosa). The patterned variation has distinct compositions within the byproducts and products that are quantifiable. The differences in processing are a result of several factors including

type of cultivation, crop type, ultimate use of product, seed morphology, and regional stylistic variation. There are a variety of harvesting choices depending on whether the crop is a Type A or a Type B variety (see chapter 4 or glossary). The choice of harvesting also effects the processing pathways with respect to the inclusion of weeds, the amount of by-product cleaning, and the number of cleanings done at each stage. A major contribution of this study is the demonstration that harvesting styles (particularly the difference between Type I and Type II methods) has a direct effect on the compositions of the successive products and byproducts down the processing pathway.

The isolation of variables which distinguish the byproducts and products of specific millet crop processing stages, and the development of millet crop processing models (for Type A and Type B millet crops) specifically tailored for archaeological interpretations were the main themes of chapter 5. Ethnographic models were presented for the processing of Type A millet crops such as Sorghum bicolor and Pennisetum typhoides, and Type B crops such as Setaria tomentosa (growing with weeds) and Panicum miliare (growing without weeds). The models are flexible and facilitate any adjustments needed as a result of varying harvesting methods. Most importantly, the ethnographic models aid in the archaeological elucidation of cultivation versus procurement of grains from elsewhere.

PALEOETHNOBOTANICAL RECONSTRUCTION

The paleoethnobotanical reconstruction in this dissertation (chapters 6 and 7) involved the ethnoarchaeological and archaeobotanical investigations at Oriyo Timbo and Babar Kot to determine the economic role of millet cultivation for the occupants. The archaeobotanical results indicate that there is strong evidence for the use of summer crops at both sites.

The archaeobotanical assemblage at Oriyo Timbo is dominated by weeds,

although the millet seeds also occur in strong densities. Furthermore, the Oriyo Timbo archaeobotanical assemblage consists primarily of plant seeds, and have no rachii or any other plant parts. The character and patterns in the archaeobotanical data indicate the use of millet grains primarily as human food. The paleoethnobotanical reconstruction revealed that the Late Harappan pastoral inhabitants of Oriyo Timbo were not cultivating millets at the site. Instead, they were probably bringing grain in at the onset of occupation each season, or, were trading and exchanging for grain from neighboring agriculturalists.

In contrast to Oriyo Timbo, the analysis of the Babar Kot 1990-91 archaeobotanical assemblage revealed evidence of both summer and winter crop *cultivation*, with the summer crop Setaria italica dominating the crop assemblage. Setaria sps rachis remains were also recovered and they are strong indicators of crop processing stages. The results of the paleoethnobotanical reconstruction indicate that the occupants of this Late Harappan sedentary settlement were involved in year long local cultivation of crops, primarily millets, legumes and oilseeds. The Babar Kot inhabitants certainly used millet grain as human food. Furthermore, millets appear to have been the primary food crop for the settlement and were an integral component of the economy. The pastoral (nomadic, semi-nomadic or semi-sedentary) Oriyo Timbo subsistence economy is characterized by an absence of cultivation by the site occupants, however, cultivation by the occupants elsewhere in the region has not been negated. Consequently, it has not been possible to determine whether the Oriyo Timbo inhabitants were nomadic, semi-nomadic or semi-sedentary pastoralists.

With respect to the issue of using millets as fodder, it appears that millets were brought to Oriyo Timbo as highly processed grain. The use of millets as fodder could not be definitively discerned at Babar Kot on the basis of the present data. However,

there is a strong likelihood that millet byproducts were used as fodder by the occupants given the amount of byproduct generated during local millet cultivation, and the presence of domesticated animals within a farming context.

Another significant contribution of this dissertation is the animal feeding model for the Late Harappan of Gujarat developed through ethnographic observations and archaeological inferences (chapter 8). I have proposed that the diets of the Oriyo Timbo domesticated animals primarily consisted of wild forage, while the Babar Kot domesticated animals were fed millet byproducts when available (November onwards), and that wild forage supplemented their diet during other seasons. The animal feeding model was originally intended to be tested through the use of carbon isotope data of domesticated animal bones from Oriyo Timbo and Babar Kot. However, carbon isotope analysis was not successful due to poor collagen preservation. The model can be tested when isotopic data from animal bones are available, and at that point the model's implications of various isotopic signatures can be re-evaluated.

The ethnographic and ethnoarchaeological results of this dissertation contribute to methodology and research design in the fields of archaeobotany and ethnobotany. Given our current understanding of South Asian subsistence systems, these results provide a firm foundation for future studies. This dissertation did not aim to answer all the questions regarding the Late Harappan phenomenon in Gujarat, India, but attempted to provide new approaches, and offer innovative investigatory methods to facilitate a better understanding of the subsistence and agricultural systems of the Late Harappan phase in Gujarat.

REGIONAL IMPLICATIONS OF RESULTS

The results from this dissertation have significant implications for the Late Harappan settlement and subsistence systems. I argue that the breakdown in the

Harappan integration sphere around 2000 B.C. allowed for more flexibility in settlement patterns. This opened up areas previously not occupied, and with 'millet' cultivation as the basis of the farming economy, the settlement of arid areas in Saurashtra and North Gujarat was possible. Thus, one can perceive the Late Harappan of Gujarat as having an increased integration between agriculture and animal husbandry resulting in pastoralism and agriculture complementing each other rather than representing alternative economies.

An interpretive settlement pattern model with three main alternatives was developed for the Late Harappan (chapter 9). The three systems in the model are differentiated on the basis of the degree of integration between agricultural and pastoral economies within and between groups. Given our current understanding of the archaeological data, I argue that the settlement and subsistence system during the Late Harappan period most likely involved the economic interplay between agricultural settlements and pastoral adaptations, but with limited social integration. Thus, the previous simplistic model of increased pastoralism without agriculture is rejected. Furthermore, the results of this dissertation conclude that studies of the Late Harappan phenomenon must examine the degree and exact nature of the integration between agriculture and pastoralism. More importantly, as argued by Bar-Yosef and Khazanov (1992), within specific populations, the ratio of those involved in agriculture as opposed to pastoralism has to be established to define the exact forms of pastoralism.

The archaeobotanical and ethnoarchaelogical investigations have successfully addressed the main issues of this dissertation. The study demonstrated the strong interpretive potential of applying complementary methods of investigation, specifically in the case of archaeobotany and ethnographic modeling to one issue. Additionally, the ethnographic crop processing studies and millet crop processing models developed have

global applicability. As such, the potential contributions and the necessity of subsistence studies, such as paleoethnobotany, to the examination of settlement patterns and culture change was realized.

NEW DIRECTIONS FOR FURTHER RESEARCH

As typical of most research, the results from this dissertation suggest future direction using related methods of investigation. As discussed in chapter 9, the potential pastoral adaptations during the Late Harappan were diverse and their elucidation is crucial for the understanding the onset of Late Harappan phenomenon, and its continuity and change. The most effective method to distinguish these various adaptations is through the elucidation of the integration between pastoral and agricultural economies within each group. To do this effectively, cultivation of millet crops by the occupants has to be defined. Late Harappan settlements classified as pastoralist sites must be re-evaluated within this framework. Moreover, the precise nature of pastoral adaptations during the previous period, the Mature Harappan, and their distinction and similarity with the subsequent Late Harappan pastoral adaptations needs to be defined. Their elucidation has considerable implications for understanding the nature of culture change during the third and second millennium B.C. in South Asia.

Another important avenue of further investigation entails examining regional variation in pastoral adaptations during the Mature and Late Harappan phases in the greater Indus, (particularly between Baluchistan, Sindh, Gujarat and Punjab). The greater Indus region is diverse in environment, climate, vegetation and economies, and a variation in pastoral adaptations is expected. Elucidation of this variation, its significance, and possible role in the localization of the Harappan state would have significant implications.

Regardless of whether the previous hypotheses presented in this dissertation are proven correct or not, their investigation will contribute to our understanding of the complementary and alternative subsistence economies of the Mature and Late Harappan phases in South Asia, and increase our understanding of the complexity of prehistoric systems in general. Such investigations broaden our knowledge and provide new avenues for further research.

GLOSSARY

This glossary provides information for key words and concepts used in the text, but it is not a comprehensive dictionary of archaeology or botany. An effort was made in the text to keep jargon to a minimum, although a few technical expressions are inevitable. For a pictorial representation of botanical terminology see the appropriate figures referenced in the glossary.

Caryopsis is the botanical term for the fruit of a grass plant. Other synonymous terms used for caryopsis in this dissertation include seed and grain.

Chaff is the crop component produced when the glumes/husks of the grains are removed through pounding or grinding. It is dusty in composition and preserves poorly in archaeological contexts.

Cultigen: a crop species or other taxon evolved under domestication to become distinct from its wild progenitor or progenitors.

Cultivar: a particular variety of a cultigen, usually named informally.

Free threshing is a term used in relationship to some cereals to describe the ease of dislodging the grain/caryopsis from the spikelets and glumes. The grains of such cereals are freed from their enclosing spikelets only through threshing. Examples of free threshing millets studied in this project are Sorghum bicolor and Pennisetum typhoides.

Heads/ Inflorescence heads/ Panicles/ Panicle heads: all these terms are synonymous for this study, and refer to the seed bearing part of the grass plant. In the cases of millet

crops, the seed bearing portion is a specific inflorescence form called a panicle. The panicle heads bear the seed bearing spikelets on rachillas attached on the central rachis (see figures 5-2, 5-4, 5-8, 5-10).

Headedness is the tendency for the grains (of both crop plants and weeds) to remain on the head/seed bearing structure (the panicle, or rachis, or rachilla) in spite of threshing.

Processing stages levels: Relative terminology is used to distinguish levels of processing stages. (Figures 5-3, 5-5)

Higher processing stages are those stages which are closer to the consumption product or end product such as pounding, winnowing II and grinding. They also most often occur primarily in home bases or domestic activity areas.

Lower processing stages refer to the initial stages of processing such as threshing, winnowing I and sieving, occur in the fields and home bases.

Palea and Lemma/Husk/Glumes are the outer coverings of the caryopsis/seeds/grains of grasses. These coverings may be tightly bound and hard to remove (as seen for Setaria sps and Panicum sps) or soft and easy to remove (as seen for Sorghum sps and Pennisetum sps).

Rachis(ii) is the portion of the central stalk of the grass plant that lies within the panicle. The spikelets which bear the grains are attached to the rachis either directly or through rachillas (Figures 5-2, 5-4, 5-8, 5-10).

Rachilla(s) are secondary axes on the rachis and terminate in numerous spikelets which

bear the seeds. (Figures 5-2, 5-4, 5-8, 5-10).

Sievability is the index of how easily a seed can be ethnographically sieved/separated away from of the prime products. It is dependent on seed size and weight.

Spikelets consist of the crop grains enclosed within the glumes/husks and often held on the ends of rachii or rachillas. The spikelets have to be threshed/pounded to free the grains. In the case of Sorghum and Pennisetum when the grains fall free of the rest of the spikelet they are most often naked (i.e., with no enclosing glume). In other cases, they have glumes but not the rachilla portion of the spikelet. For Panicum miliare and Setaria tomentosa, when the grain falls free it often has part of the rachilla attached, and only pounding totally frees the grain. (Figures 5-2, 5-4, 5-8, 5-10).

Type A crops is the term given to crops that can be harvested in a particular manner, termed Type I method of harvest (Figure 4-7). Examples include Pennisetum typhoides, Sorghum bicolor. The processing of these crops is similar to that for free threshing cereals (as discussed by Hillman 1983).

Type I harvest method typically involves only cutting the panicle heads, leaving the stalks behind (Figure 4-7). The harvest cut occurs at the base of the panicle heads, and this represents a specific selection for only the seed bearing parts of the plants as the starting product of processing.

Type B crops include small grained plant crops such as Setaria sps and Panicum sps which are only harvested by a particular method, termed Type B method of harvest. The processing of these crops is similar to that for glume wheats (as discussed by

Hillman 1983).

Type II harvest method involved the cutting of the panicle heads, the stalks, and most often they are cut at the base of the plant (see figure 4-2). This method incorporates weeds growing in between and around the crop plants into the processing stages. The starting product for processing includes seed bearing parts and non-seed bearing parts also. It is important to note that Type A crops can be harvested in a Type II method.

Winnowability is the index of how easily a seed is separated from the prime products through winnowing. It is dependent on seed size and weight.

BIBLIOGRAPHY

Adams, R. M.

1978 Strategies of Maximization, Stability, and Resilience in Mesopotamian Society, Settlement, and Agriculture. *Proceedings of the American Philosophical Society* 122 (5): 329-335.

1974 The Mesopotamian Social Landscape: A View from the Frontier. In *Reconstructing Complex Societies*, edited by Charlotte B. Moore, pp. 1-20. Bulletin of the American Schools of Oriental Research, Supplement 20.

Agrawal, D. P., and B. M. Pande (eds)

1977 *Ecology and Archaeology of Western India*. Delhi: Concept.

Agrawal, D. P., and R. K. Sood

1982 Ecological Factors and the Harappan Civilization. In *Harappan Civilization*, edited by G. L. Possehl, pp. 223-52. Delhi: American Institute of Indian Studies.

Aiyer, A. K. Y. N.

1982 *Field Crops of India*. Bangalore Printing and Publishing Company Ltd. Bangalore, India.

Allchin, B., and A. Goudie

1971 Dunes, Aridity and Early Man in Gujarat, Western India. *Man* 6: 248-65.

Allchin, B., A. Goudie, and K. Hegde

1978 *The Prehistory and Paleogeography of the Great Indian Desert*. New York: Academic Press.

Ambrose, S. H., and M. DeNiro

1987 Bone Nitrogen Isotope Composition and Climate. *Nature* 324: 201.

Bar-Yosef, O., and A. Belfer-Cohen

1992 From Foraging to Farming in the Mediterranean Levant. In *Transitions to Agriculture in Prehistory*, edited by A. B. Gebauer and T.D. Price, pp. 21-48. Monographs in World Archaeology No.4, Prehistory Press: Madison.

Bar-Yosef, O., and A. Khazanov

1992 *Pastoralism in the Levant: Archaeological Materials in Anthropological Perspectives*. Monographs in World Archaeology No. 10. Prehistory Press, Madison, Wisconsin.

Barnard, G., and Kristoferson, L.

1989 *Agricultural Residues as Fuel in the Third World*. Earthscan, Energy Information Programme Technical Report No. 4. The Beijer Institute, The Royal Swedish Academy of Science.

Belcher, W.R.

1991 Fish Resources in an Early Urban Context at Harappa. In *The Archaeology of 3rd millennium Urbanism at Harappa (Pakistan)*, edited by Richard Meadow, pp. 107-120 Prehistory Press: Madison.

Bhan, Kuldeep K.
1989 Late Harappan Settlements of Western India with Specific Reference to Gujarat. In *Old Problems and New Perspectives in the Archaeology of South Asia*, edited by J.M.Kenoyer, pp. 61-74, Wisconsin Archaeological Reports, Vol. 2.

Bhandari, M.N.
1974 Famine Foods in the Rajasthan Desert. *Economic Botany* 28: 73-81.

1978 *Flora of the Indian Desert.*

Bharadwaj, O.P.
1961 The Arid Zone of India and Pakistan. In *A history of Land use in Arid Regions*, edited by L.D. Stamp, pp. 143-74, Paris: UNESCO, Arid Zone Research.

Binford, L. R.
1977 General Introduction. In *For Theory Building in Archaeology* edited by L. R. Binford, pp. 1-10. Academic Press, New York.

1981 *Bones: Ancient Man and Modern Myths.* Academic Press, New York.

Bisht, R. S.
1990 Dholavira: New Horizons of the Indus Civilization. *Puratattva* 20: 71-82.

Bohrer, Vorsila L.
1986 Guidelines in Ethnobotany. *Journal of Ethnobiology* 6(1): 27-43.

Bottema, S.
1984 The Composition of Modern Charred Seed Assemblages. In *Plants and Ancient Man*. edited by W. van Zeist and W. A. Casperie, pp. 207-212. Boston: A. A. Blakema.

Cane, S.
1989 Australian Aboriginal Seed Grinding and its Archaeological Record: A Case Study from the Western Desert. In *Foraging and Farming: The Evolution of plant exploitation*, edited by D. R. Harris and G. C. Hillman, pp. 99-119. Unwin Hyman: London.

Caswell, H., F. Reed, S. N. Stephenson, and P. A. Werner.
1973 Photosynthetic Pathways and Selective Herbivory: A Hypothesis. *The American Naturalist* 107 (956): 465-480.

Chakrabarti, D. K.
1984 Origins of the Indus Civilization: Theories and Problems. In *Frontiers of the Indus Civilization*, edited by Lal, B. B., and Gupta, S. P., pp. 43-40. Indian Archaeological Society, New Delhi.

Chalam, G.V., and J. Venkateswarlu
1965 *An Introduction to Agricultural Botany in India.* Vol I. Bombay: ASIA.

Charles, M. P.
1990 Traditional Crop Husbandry in Southern Iraq. *Bulletin on Sumerian Agriculture*. 5: 47-64.

Chisholm, B. S., D. E. Nelson and H. P. Schwartz.
1983 Marine and Terrestrial Protein in Prehistoric Diets on the British Columbia Coast. *Current Anthropology* 24:396-398.

Clark, J. G. D.
1954 *Excavations at Starr Carr: An Early Mesolithic Site at Seamer, near Scarborough, Yorkshire*. London: Cambridge University Press.

Clarke, D. L.
1973 Archaeology: The Loss of Innocence. *Antiquity* 47: 6-18.

Cobley, L. S.
1956 *An Introduction to the Botany of Tropical Crops*. Longmans Green and Co: London.

Cooke, R.
1992 Prehistoric Nearshore and Littoral Fishing in the Eastern Tropical Pacific: An Icthyological Evaluation. *Journal of World Prehistory*, Vol.6 (1): 1-50.

Constantini, L.
1984 The Beginning of Agriculture in the Kachi Plain: The Evidence of Mehrgarh. In *South Asian Archaeology* edited by B. Allchin, pp. 29-33. Cambridge University Press: Cambridge.

1987 Vegetal Remains. In *Prehistoric and Protohistoric Swat, Pakistan (c.3000-1400 B.C)*, edited by G. Stacul, pp. 155-65. Appendix B. Rome: Ismeo.

Dales, G. F. and J. M. Kenoyer.
1990 Excavation at Harappan - 1988. *Pakistan Archaeology* 24: 68-176.

1991 The Harappa Project 1986-1989: New Investigations at an Ancient Indus City. In *Harappan Civilization: A Contemporary Perspective* edited by G. L. Possehl. 2nd edition. Oxford and IBH, New Delhi.

1979 The Balakot Project: Summary of Four Years' Excavations in Pakistan. In *South Asian Archaeology 1977* edited by M. Taddei, pp. 241-73. Naples: IsMEO.

DeNiro, M.
1985 Postmortem Preservation and Alteration of in vivo Bone Collagen Isotope Ratios in Relation to Paleodietary Reconstruction. *Nature* 317: 806-809.

DeNiro, M., and S. Epstein.
1978 Influence of Diet on Distribution of Carbon Isotopes in Animals. *Geochemica et Cosmochemica Acta* 42: 495-506

1981 Influence of Diet on the Distribution of Nitrogen Isotopes in Animals. *Geochemica Cosmochemica Acta* 45: 341-351.

Dennell, R. W.
1972 The Interpretation of Plant Remains: Bulgaria. In *Papers in Economic Prehistory* edited by E. S. Higgs, pp.149-50. Cambridge.

1974 Prehistoric Crop Processing Activities. *Journal of Archaeological Science* 1: 275-84

1976 The Economic Importance of Plant Resources Represented on Archaeological Sites. *Journal of Archaeological Sciences* 3: 229-247.

Dikshit, R. B. K. N.
1938 *Prehistoric Civilization of the Indus Valley*. Madras: University of Madras Press.

Dixit, A.S., S.S. Dixit and Vishnu-Mittre.
1987 The Occurrence of *Eleucine africana* Kennedy O'Byrne in India and Its Significance in the Origin of *Eleucine coracana*. *Proceedings of the Indian Academy of Sciences (Plant Sciences)* 97(1):1-10.

Dodia, R.
1988 Climate of Kashmir during the last 700,000 years: The Baltal Pollen Profile. *Proceedings Indian National Science Academy* 54 A(3): 481-89.

Dodia, R., A. C. Gupta, C. Mandavia, C. Charma and A. Vora
1982 Palynological Investigations on the Lower Karewas, Kashmir. *Man and Environment* 6:21-26.

Ellen, R.
1982 *Environment, Subsistence and System*. Cambridge University Press, Cambridge.

Fairservis, W. A.
1956 Excavations in the Quetta Valley, West Pakistan. *Anthropology Papers of the American Museum of Natural History* 45 (part 2).

1973 Preliminary Report on Excavations at Alladino (First Season, 1973). *Pakistan Archaeology*. 9: 95-102.

Flam, L.
1981 *The Paleography and Prehistoric Settlement Patterns in Sind, Pakistan (ca 4000-2000 B.C.)*, PhD Dissertation, University of Pennsylvania, Philadelphia.

1986 Recent Explorations in Sind: Paleography, Regional Ecology and Prehistoric Settlement Patterns. In *Studies in the Archaeology of India and Pakistan*, edited by J. Jacobson, pp. 65-89. Oxford and IBH, New Delhi.

Flannery, K. V. (ed)
1976 *The Early Mesoamerican Village*, New York: Academic Press.

Ford, Richard I.
1978 *The Nature and Status of Ethnobotany*. University of Michigan Museum Anthropology papers, No. 60.

1979 Paleoethnobotany in American Archaeology in *Advances in Archaeological Method and Theory* 2, ed. M.Schiffer, pp. 285-336, New York: Academic Press.

1985 *Prehistoric Food Production in North America*. No. 75. Ann Arbor: Museum of Anthropology.

Friedman, J.
1974 Marxism, Structuralism and Vulgar Materialism. *Man* 9: 444-69.

Fritz, G.J.
1990 Multiple Pathways to Farming in Precontact Eastern North America. *Journal of World Prehistory*, Vol.4 (4): 387-436.

Gosh, S. S., and K. R. Lal.
1963 Plant Remains from Rangpur. *Ancient India* 18-19: 161-77.

Government of India.
1908 *Imperial Gazetteer of India*. Vol 15. (New Edition).

Green, F.J.
1979 Phosphate Mineralization of Seeds from archaeological sites. *Journal of Archaeological Science*. 6:279-284.

Gupta, H.P.
1971a Pollen Analytical Investigations of Some Upper Pleistocene Samples from Tocklai, Cinnamara, Assam. *The Paleobotanist* 18 (3): 234-236.

1971b Studies of Indian Pollen Grains -IV Boraginaceae. *Geophytology*: pp.127-34.

Gupta, S.K.
1977 Holocene setting in the Little Rann of Kutch. In *Ecology and Archaeology of Western India*. edited by O.P Agrawal and B.M. Pande, pp. 201-205. Delhi.

Gupta, H.P., and C. Sharma
1982 Quaternary Palynostratigraphy in India: A Critical review. *Special Publication of the Palaeontological Society of India*. 1: 130-38.

Gupta, S. P.
1979 *Archaeology of Soviet Central Asia and the India Borderlands*. 2 vols. Delhi: B.R. Publishing Co.

Harris, D. R.
1989 An Evolutionary Continuum of People-plant Interaction. In *Foraging and Farming: The Evolution of Plant Exploitation*, edited by D. R. Harris and G. C. Hillman, pp. 11-26. Unwin Hyman: London.

Harris, D. R., and G. C. Hillman (eds).
1989 *Foraging and Farming: The Evolution of plant Exploitation*, Unwin Hyman: London.

Harris, M.
1979 *Cultural Materialism: The Struggle for a Science of Culture*. New York: Vintage Books.

Hastorf, C. A.
1990 The Effects of the Inka State on Sausa Agricultural Production and Crop Consumption. *American Antiquity*, Vol 55(2): 262-290.

Hastorf. C. A., and V. S. Popper (eds).
1988 *Current Paleoethnobotany: Analytical Methods and Cultural Interpretations of Archaeological Plant Remains*. The University of Chicago Press, Chicago and London.

Heath, M. E., R. F. Barnes and D. S. Metclalfe.
1985 *Forages: The Science of grassland agriculture*, 4th edition. Iowa State University Press: Ames.

Hegde, K.
1977 Late Quaternary Environments in Gujarat and Rajasthan. In *Ecology and Archaeology of Western India* edited by D. P. Agrawal and B. M. Pande, pp. 169-80. Delhi: Concept Pub Co.

Helbeak, H.
1959 The Domestication of Food Plants in the Old World. *Science* 130: 365-372.

Herman, F.
1991 *Bronze Age Complexes in Gujarat Before the Harappan Urbanization Expansion: A Working Hypothesis*. Master Thesis, Department of Anthropology, University of Pennsylvania, Philadelphia.

Higgs, E. S. (ed)
1975 *Paleoeconomy*, Cambridge: Cambridge University Press.

1972 *Papers in Economic Prehistory*, London: Cambridge University Press.

Hillman, G.
1981 Reconstructing Crop Husbandry Practices from the Charred Remains of Crops. In *Farming Practice in British Prehistory*, edited by R. J. Mercer, pp.123-162. Edinburgh: Edinburgh University Press.

1984 Interpretation of Archaeological Plant Remains: the Application of Ethnographic Models from Turkey. In *Plants and Ancient Man: Studies in Paleoethnobotany* edited by W.V. Zeist and W.A. Casperie, pp.1-41. Rotterdam: Balkema.

1985 Traditional Husbandry and Processing of Archaic Cereals in Recent Times: the Operations, Products and Equipments That Might Feature in Sumerian Texts. Part I: The Glume Wheats. *Bulletin on Sumerian Agriculture* 1: 114-152. Part II: The Free Threshing Cereals. *Bulletin on Sumerian Agriculture* 2: 1-31.

Hillman, G. C., and M. S. Davies.
1990 Measured Domestication Rates in Wild Wheats and Barley Under primitive Cultivation, and their Archaeological Implications. *Journal of World Prehistory*, vol. 4, No.2: 157-222.

Ho, P.
1975 *The Cradle of East*. Chicago: University of Chicago Press.

Hodder, I.
1982 *The Present Past*. London.

Hutchinson, J
1977 India: Local and Introduced Crops. In *The Early History of Agriculture* edited by J. Hutchinson, G. Clarke, E. M. Jope and R. Riley. pp. 129-141. Oxford: Oxford University Press for the British Academy.

Jacobson, J.
1987 The Harappan Civilization: An Early State. In *Studies in the Archaeology of India and Pakistan* edited by J. Jacobson, pp. 137-174. Oxford and IBH, New Delhi.

Jarrige, J. F.
1986 Excavation at Mehrgarh-Nausharo. *Pakistan Archaeology* 10-22: 62-131.

1988 Excavations at Nausharo. *Pakistan Archaeology* 23: 149-203.

Jarrige, J. F., and R. H. Meadow.
1980 The Antecedents of Civilization in the Indus Valley. *Scientific American* 243 (2): 122-133.

Jones, G.
1983 *The Use of Ethnographic and Ecological Models in the Interpretation of Archaeological Plant Remains: Case Studies from Greece*. Unpublished Dissertation for the University of Cambridge.

1984 Interpretation of Archaeological Plant Remains: Ethnographic Models from Greece. In *Plants and Ancient Man: Studies in Paleoethnobotany* edited by W.V. Zeist and W.A. Casperie, pp. 43-61. Rotterdam: Balkema.

1987 A Statistical Approach to the Archaeological Identification of Crop Processing. *Journal of Archaeological Science* 14: 311-323.

1988 The Application of Present Day Cereal Processing Studies to Charred Archaeobotanical Remains. *Circeae* 6 (2): 91-96.

Jones, G. E. M., K. A. Wardle, P. L. J. Halsteadt and D. Wardle.
1986 Crop Storage at Assiros. *Scientific American* 254 (3): 96-103.

Joshi, J. P., M. Bala, and J. Ram.
1984 The Indus Civilization: A Reconsideration on the Basis of Distribution Maps. In *Frontiers of the Indus Civilization* edited by B. B. Lal and S. P. Gupta, pp. 511-530. Books and Books, New Delhi.

Khazanov, A.
1984 *Nomads and the Outside World*. Cambridge: Cambridge University Press.

Kenoyer, J. M.
1989 Socio-economic Structure of the Indus Civilization as Reflected in Specialized Crafts and the Question of Ritual Segregation. In *Old Problems and New Perspectives in the Archaeology of South Asia*, edited by J.M. Kenoyer, pp.183-192. Wisconsin Archaeological Reports, Vol. 2.

1991 The Indus Valley Tradition of Pakistan and Western India. *Journal of World Prehistory* Vol.5, 4: 331-385.

Kent, S.
1989 The Myth of Ecological Determinism - Anticipated Mobility and Site Spatial Organization. In *Farmers as hunters The implications of sedentism*, New Directions in Archaeology edited by S. Kent, pp. 96-130, Cambridge University Press: Cambridge.

Kajale, M.D.
1974 Ancient Grains from India. *Bulletin of the Deccan College Research Institute*. 34 (1-4):55-74.

1988 Plant Economy. In *Excavations at Inamgoan* edited by M.K.Dhavalikar and H.D. Sankalia. Volume One: Part II pp. 727-821. Pune: Deccan College Postgraduate and Research Institute.

Keepax, C.
1977 Contamination of Archaeological Deposits by Seeds of Modern Origin With Particular Reference to the Use of Flotation Machines. *Journal of Archaeological Sciences* 4: 221-29.

Kohl, P.L.
1981 Materialist Approaches in Prehistory. *Ann Rev Anthropology* 10: 89-118.

Kramer, C.
1979 *Ethnoarchaeology: Implications of Ethnography for Archaeology*. Columbia University Press, New York.

Lamberg-Karlovsky, C. C.
1982 Sumer, Elam and the Indus: Three Urban Processes Equal One Structure? In *Harappan Civilization: A Contemporary Perspective* edited by G.L.Possehl.pp. 61-68. Oxford and IBH Pub Co.

Larson, D. O., and J. Michaelsen.
1990 Impacts of Climatic Variability and Population Growth on Virgin Branch Anasazi Cultural Developments. *American Antiquity*, 55(2): 227-249.

Lattimore, O.
1962 *Inner Asian frontiers of China*. Beacon Press, Boston.

Leacock, E.
1972 Introduction. In *The Origin of the Family, Private Property and the State*. F. Engels, New York: Int. Publ, New Work Paperbacks.

Lees, S.H. and Bates, D. G.
1974 The Origins of Specialized Nomadic Pastoralism: A Systemic Model. In *American Antiquity* 39(2): 187-193.

Leshnik, L.S
1968 Prehistoric Exploration in North Gujarat and Parts of Rajasthan. *East and West* 18 (3-4): 295 -310.

MacNeish, R. S.
1972 *The Prehistory of Tehuacan Valley*. Vol. 5: Excavation and Reconnaissance, Austin: University of Texas Press.

1978 *The Science of Archaeology?* Belmon: Duxbury.

Mackay, E. J. H.
1943 *Chanhu-daro Excavation 1935-36*. Boston: Museum of Fine Arts, American Oriental Series.

Mann, H.H.
1955 *Rainfall and Famine: A study of rainfall in the Bombay Deccan, 1865-1938.* Bombay: Indian Society of Agricultural Economies.

Marshall, S. J.
1931 *Mohenjo-daro and the Indus Civilization.* A. Probsthain, London.

Meadow, R.
1971 The Emergence of Civilization. In *Man, Culture and Society*, edited by H. Shapiro, pp. 112-67.

1989 Continuity and Change in the Agriculture of the Greater Indus Valley: The Paleobotanical and Zooarchaeological Evidence. In *Old Problems and New Perspectives in the Archaeology of South Asia*, edited by J.M. Kenoyer, pp.61-74. Wisconsin Archaeological Reports, Vol. 2.

1991 Faunal Remains and Urbanism at Harappa. In *The Archaeology of 3rd millennium Urbanism at Harappa (Pakistan)* edited by Richard Meadow, pp. 189-106 Prehistoric Press: Madison.

Meher-Homji, V.M.
1989 History of Vegetation of Peninsular India *Man and Environment* 13: 1-10.

Mehra, K. L.
1963 Considerations of the African Origin of *Eleucine* coracana (L.) Gaertn. *Current Science* 7:300-301.

Miksicek, C.
1987 Formation Processes of the Archaeobotanical Record. *Advances in Archaeological Method and Theory* 10: 211-247.

Miller, N. F.
1984 The Use of Dung as Fuel: An Ethnographic Example and An Archaeological Application. *Paleorient* vol. 10/2: 71-79.

Miller, N. F., and T. L. Smart.
1984 Intentional Burning of Dung Fuel: A Mechanism for the Incorporation of Charred Seeds into the Archaeological Record. *Journal of Ethnobiology* 4:15-28.

Morgon, L. H.
1877 *Ancient Society*. New York: Holt.

Mughal, M. R.
1982 Recent Archaeological Evidence from Bhawalpur. *Man and Environment* 4: 93-98.

1988 Genesis of the Indus Valley Civilization. *Lahore Museum Bulletin*, 1 (1): 45-54. Karachi: National Book Foundation.

Patel, G.
1977 *Gujarat's Agriculture*. Ahmedabad.

Pearsall, D. M.
1989 Interpreting the Meaning of Macroremain Abundance: The Impact of Source and Context. In *Current Paleoethnobotany: Analytical Methods and Cultural Interpretations of Archaeological Plant Remains* edited by Hastorf. C. A., and V. S. Popper. pp. 97-118. University of Chicago Press, Chicago and London.

1982 Phytolith Analysis: Applications of a New Paleoethnobotanical Technique in Archaeology, *American Anthropologist* 84: 862-871.

Piggott, S.
1962 *Prehistoric India* (2nd edition). London: Cassell.

Plog, S.
1977 Explaining Change. In *Explanation of Prehistoric Change*, J. Hill (ed.) Albuquerque: University of N. Mexico Press.

Possehl, G.L.
1976 Lothal: A Gateway Settlement of the Harappan Civilization. In *Ecological Backgrounds of South Asian Prehistory* edited by K.A.R. Kennedy and G.L. Possehl, pp. 118-31. Ithaca: Cornell University, South Asia Occasional Papers and Theses, No. 4.

1979 Pastoral Nomadism in the Indus Civilization: An hypothesis. In *South Asian Archaeology, 1977*, edited by Taddei, M., pp. 537-551. Istituto Universitario Orientale, Naples.

1980 *Indus Civilization in Saurashtra*. B. R., Delhi.

1986 African Millets in South Asian Prehistory, In *Studies in the Archaeology of India and Pakistan*, edited by Jerome Jacobson, pp.137-174. New Delhi: Oxford & IBH.

1979 Pastoral Nomadism in the Indus Civilization: An Hypothesis. *South Asian Archaeology 1977* edited by M. Taddei, Volumn 1: 537-551.

1990 *A Report on the Excavations at Oriyo Timbo*. Report submitted to the Government of India.

Possehl, G. L., and M. H. Raval.
1989 *Harappan Civilization and Rojdi*. Oxford and IBH Publishing Company Pvt. Ltd: New Delhi. American Institute of Indian Studies.

1991 *Excavations at Babar Kot 1991*. Report submitted to the Government of India.

Price, T.D., M.J. Schoeninger and G. J. Armelagos
1985 Bone Chemistry and Past Behavior: an Overview. *Journal of Human Evolution* 14: 419-447.

Purseglove,
1979 *Tropical Crops: Monocotyledons*. London: Longman.

Rachie, K., and J. V. Majmudar.
1980 *Pearl Millet*. The Pennsylvania State University Press: University Park and London.

Raikes, R. L., and R. H. Dyson.
1961 The Prehistoric Climate of Baluchistan and the Indus Valley. *American Anthropologist* 63: 265-281.

Randhawa, M.S
1962 *Agriculture and Animal Husbandry in India*. Indian Council of Agricultural research, New Delhi.

1980 *A History of Agriculture in India*. New Delhi: Indian Council of Agricultural Research.

Rao, K. E., J. M. J. de Wet, B. E. Brink and M. H. Mengesha
1987 Intraspecific Variation and Systematics of Cultivated *Setaria italica*, Foxtail millet, *Economic Botany* 41(1): 108-116.

Rao, S.R.
1973 *Lothal and the Indus Civilization*. Asia Publishing House, Bombay.

Rasmussen, P.
1993 Analysis of Goat/Sheep Feaces from Egolzwil 3, Switzerland: Evidence for Branch and Twig Foddering of Livestock in the Neolithic. *Journal of Archaeological Science* 20: 479-502.

Rathje, W. L., and M. B. Shiffer.
1982 *Archaeology*. New York: Harcourt, Brace.

Ratnager, S.
1986 An aspect of Harappan agricultural production. *Studies in History* 2: 137-153.

Reddy, S. N.
1991a Complementary Approaches to Late Harappan Subsistence: An Example from Oriyo Timbo. In *The Archaeology of 3rd millennium Urbanism at Harappa (Pakistan)* edited by Richard Meadow, pp. 127-135 Prehistoric Press: Madison.

1991b Archaeobotany at Oriyo Timbo 1989-90: A post urban site in Gujarat. *Man and Environment* Vol.16:1, pp. 73-84.

1991c Opportunistic Cultivation: An Ethnographic Study in South India. *Expedition* Vol.33 (3):18-26.

Renfrew, J. M.
1973 *Paleoethnobotany*. New York: Columbia University Press.

Rissman, P.
1985 Migratory Pastoralism in Western India in the Second Millennium B.C.: The Evidence from Oriyo Timbo. PhD Dissertation, Department of Anthropology, University of Pennsylvania.

1985 The Oriyo Test Excavation and the End of the Harappan Tradition in Gujarat. *South Asia Archeology 1983* edited by J. Schotsmans and M. Taddei, Naples: Universitario Orientale, Dipartmento di Studi Asiatici, Series Minor XXIII: 345-55.

1987 The Potential of Annular Analysis for South Asian Archaeology. *Man and Environment* XI: 15-24.

Rissman, P.C., and Y.M. Chitalwala.
1990 *Harappan Civilization and Oriyo Timbo*. Oxford and IBH Publishing Company Pvt. Ltd.: New Delhi and American Institute of Indian Studies.

Ryan, K.
1990 The Faunal Remains from Oriyo Timbo, Gujarat. In *A Report on the Excavations at Oriyo Timbo*, edited by G. L. Possehl, Report submitted to the Government of India.

1991 Archaeozoology. In *Excavations at Babar Kot 1991* edited by G. L. Possehl and M. H. Raval, Report submitted to the Government of India.

Sanders, W. T., and B. Price.
1968 *Mesoamerica: The Evolution of a Civilization*. New York: Random House.

Saraswat, K.S.
1981 Plant Economy in Ancient Sringaverapura Phase - IC (c. 1050-1000 B.C). *Puratattva* 12:11-87.

Savitri, R., and Vishnu-Mittre.
1978 *Setaria* sps in Ancient plant economy of India. *The Palaeobotanist* 25: 539-62.

Schoeninger, M. J., and M. J. DeNiro.
1984 Nitrogen and Carbon Isotope Composition of Bone Collagen from Marine and Terrestrial Animals. *Geochemica et Cosmochemica Acta* 48: 625-637.

Schoeninger, M. J., M. J. DeNiro, and H. Tauber.
1983 Stable Nitrogen Isotope Ratios of Bone Collagen Reflect Marine and Terrestrial Components of Prehistoric Human Diet. *Science* 220: 1381-1383.

Schwarcz, H. P., and M. J. Schoeninger.
1991 Stable Isotope Analysis in Human Nutritional Ecology. *Yearbook of Physical Anthropology* 34: 283-321.

Sealy, J. C., and N. J. Van der Merwe.
1986 Isotope Assessment and the Seasonal Mobility Hypothesis in the South Western Cape of South Africa. *Current Anthropology* 27(2): 135-150.

Shaffer, J. G.
1981 The Protohistoric Period in the Eastern Punjab: A Preliminary Assessment. In *Indus Civilization* edited by A. H. Dani, pp. 65-102. Qaid-i-Azam University, Islamabad.

1991 The Indus Valley, Baluchistan and Helmand Traditions: Neolithic through Bronze Age. In *Chronologies in Old World Archaeology* edited by R. Ehrich, 3rd edition, Vol. 1: 441-464. University of Chicago Press, Chicago.

Shaffer, J. G., and D. A. Lichtenstein.
1989 Ethnicity and Change in the Indus Valley Cultural Tradition. In *Old Problems and New Perspectives in the Archaeology of South Asia*, edited by J.M. Kenoyer, pp. 117-126. Wisconsin Archaeological Reports, Vol. 2.

Sharma, A.K.
1992 The Harappan Horse was Buried Under the Dunes of ... *Puratattva* 23: 30-34.

Shiffer, M. B.
1976 *Behavioral Archaeology*. Academic Press: New York.

1983 Toward the Identification of Formation Processes. *American Antiquity* 48 (4): 675-706.

Singh, G.
1971 The Indus Valley Culture Seen in the Context of Post-Glacial Climatic and Ecological Studies in North-west India. *Archaeology and Physical Anthropology in Oceania* 6(2): 177-89.

1977 Stratigraphic and Palynological Evidence for Desertification in the Great Indian Desert. *Annals of the arid Zone* 16 (3): 310-20.

Spate, O.H.K., and A.T.A. Learmouth.
1967 *India and Pakistan. A General and Regional Geography*. (3rd edition). London: Methuen.

Steward, J.H.
1938 *Basin-plateau Aboriginal Sociopolitical Groups*. Bureau of American Ethnology Bulletin 120, Washington.

1955 *Theory of Culture*. Urbana: University of Illinois

1977 *Evolution and Ecology: Essays on Social Transformation*. Urbana: University of Illinois.

Stiles, D.
1977 Ethnoarchaeology: A Discussion of Methods and Applications. *MAN*, Vol 12 (1): 87-103.

Thiebault, S.
1988 Paleoenvironment and Ancient Vegetation of Baluchistan Based on Charcoal Analysis of Archaeological Sites. *Proceedings of the Indian National Science Academy* 54 (3): 501-509.

Tremaine, K.J.
1992 Investigation of a Nineteenth-century Threshing Floor at Mission Santa Ines (CA-SBA-518). *Pacific coast Archaeological Society Quarterly*, Vol. 28 (2): 35-47.

Tuross, N., M. L. Fogel, and P.E. Hare.
1988 Variability in the Preservation of the Isotopic Composition of Collagen from Fossil Bone. *Geochemica et Cosmochemica Acta* 52: 929-935.

Van Zeist, W., and W. A. Casperie (eds).
1984 *Plants and Ancient Man: Studies in Paleoethnobotany*, Rotterdam: Balkema.

Van der Merwe.
1982 Carbon Isotopes, Photosynthesis and Archaeology. *American Scientist* 70: 596-606.

Vavilov, N. I.
1959 *The Origin, Variation and Breeding of Cultivated Plants*. New York: Ronald Press Co.

Vishnu-Mittre
1985 The Uses of Wild Plants and the Process of Domestication in the Indian Sub-continent. In *Recent Advances in Indo-Pacific Prehistory* edited by V.N.Misra and P. Bellwood. pp. 281-291. Delhi: Oxford and IBH.

1982 The Harappan Civilization and the Need for a New Approach. In *Harappan Civilization* edited by G.L. Possehl. New Delhi: Oxford and IBH.

Vishnu-Mittre and R. Savitri,
1982 Food Economy of the Harappan. In *Harappan Civilization* edited by G. L. Possehl, pp. 205-222. Delhi: American Institute of Indian Studies.

Wadia, D.N
1966 *Geology of India*. Third Edition. London: Macmillan.

Wagner, G.E
1982 *Flotation for Small-artifact Recovery at Oriyo Timbo*. Philadelphia: University Museum, University of Pennsylvania.

1985 Botanical Remains. In Preliminary Report: Excavations at Rojdi 1983-84. *Man and Environment* Vol IX.

1989 Comparability Among Recovery Techniques. In *Current Paleoethnobotany: Analytical Methods and Cultural Interpretations of Archaeological Plant Remains* edited by Hastorf. C. A., and V. S. Popper. pp. 17-35 University of Chicago Press, Chicago and London.

Weber, S.
1992 South Asian Archaeological Variability. In *South Asian Archaeology 1989* edited by C. Jarrige with assistance of John P. Gerry and Richard H. Meadow, pp. 283-29-. Monographs in World Archaeology No. 14. Prehistory Press.

1991 *Plants and Harappan Subsistence*. American Institute of Indian Studies. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.

1989 *Plants and Harappan Subsistence: An example of Stability and Change from Rojdi*. PhD Dissertation for the Department of Anthropology, University of Pennsylvania, Philadelphia.

Werth E.
1937 Geography and History of Millets. *Angewandte Botanik* 19: 41.

Wetterstrom, W. E.
1978 Cognitive Systems, Food Patterns, and Paleoethnobotany. In *The Nature and Status of Ethnobotany* edited by R. Ford, No. 67, pp. 81-96, Ann Arbor: Museum of Anthropology.

1988 The Agricultural Economy of an Old Kingdom Town in Egypt's West Delta: Insights from the Plant Remains. *Journal of Near Eastern Studies* No. 3: 159-173 .

Wilhemy, H.
1969 Das Urstromtal am Ostrand der Iduse bene und das Sarasvati Problem. *Zeitschrift fur Geomorphologie* 8: 76-91.

Wills, W.H
1992 Foraging Systems and Plant Cultivation during the Emergence of Agricultural Economies in the Prehistoric American Southwest. In *Transitions to Agriculture in Prehistory* edited by A. B. Gebauer and T.D. Price, Monographs in World Archaeology No.4 pp. 153-176, Prehistory Press: Madison.

Wilson, J. R. and C. W. Ford.
1971 Temperature Influences on the Growth, Digestibility and Carbohydrate Composition of Two Tropical Grasses *Panicum maximum* var *trichoglume* and *Setaria spaceolata*, and Two Cultivars of the Temperate Grass *Lolium perenne*. *Australian Journal of Agricultural Research* 22: 563-571.

Yoffee, N.
1977 The Economic Role of the Crown in the Old Babylonian Period. In *Bibliotheca Mesopotamica* 3 (Malibu).